CHAPTER 14

AIR CONDITIONING AND REFRIGERATION

A Utilitiesman is expected to know technical informaiton about the air conditioning of buildings and the refrigeration of perishable products. This chapter covers the aspects of selecting and installing air-conditioning and refrigeration equipment. The individual components required in an air-conditioning system and a refrigeration system are also discussed. Finally, the fundamental electrical knowledge you actually need to install, maintain, and repair air-conditioning and refrigeration equipment is discussed.

SELECTION AND INSTALLATION OF AIR-CONDITIONING SYSTEMS

There are two types of air-conditioning systems that must be considered before selection and installation of equipment. The first system discussed is forced air. Then, in turn, the hot and chilled water system is discussed.

FORCED AIR

Forced air units are used when the areas to be air-conditioned are close to each other, are being used for similar purposes, or have the same humidity and comfort zone requirements. A few examples are office spaces, single-dwelling homes, and single-purpose shops. Some characteristics of the system that must be taken into consideration during the planning phase are the following: to keep units centrally located, to ensure return air is drawn from the area being cooled, and to ensure that one thermostat controls the system. See figure 14-1 for two examples of a forced air unit with accompanying ductwork.

HOT AND CHILLED WATER

Hot and chilled water units should be used when the areas to be air-conditioned are dispersed, have a wide range of different uses, or have different humidity and comfort zone requirements. Some examples are a barracks, a galley, or a hospital. Some characteristics of these air-conditioning units that must be taken into consideration regarding this system are location (mechanical room), use or non-use of return air (hospital operating room), humidity and temperature controls, individual room temperature requirements, and amount of installation space for piping and ductwork. See figure 14-2 for a typical piping diagram of a year-round air-conditioning system.

If you are involved in designing an air-conditioning system or desire more information, refer to NAVFAC DM 3.3, *Heating Ventilating Air-Conditioning and Dehumidifying Systems.*

HEAT LOAD CALCULATIONS AND AIR MOVEMENT

Once the type of air-conditioning system has been chosen, the next step is to figure out its appropriate size. There are two primary factors that must be considered. The first factor is heat load calculation. Humidity comfort temperature, and psychometrics are the three primary considerations necessary for calculating heat load. The second factor is air movement. Velocity, pressure, and drafts are the three main factors that are important when you are designing and planning the size

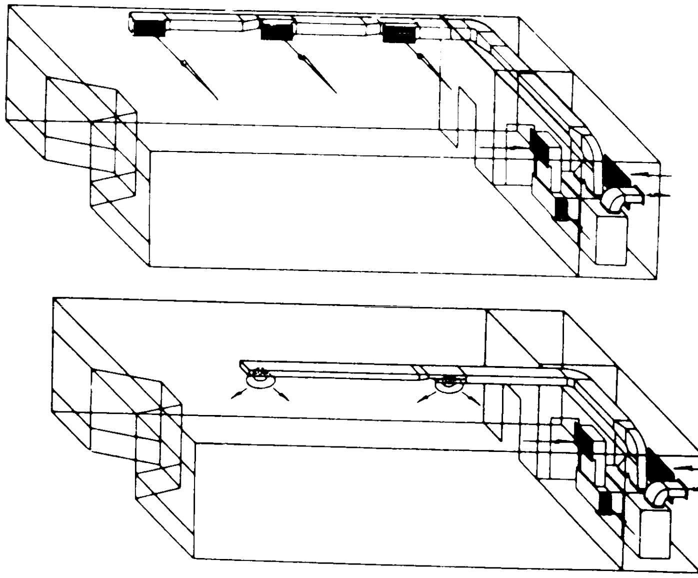

Figure 14-1.—Arrangements for package-type air-conditioning units and air ducts. 87.185

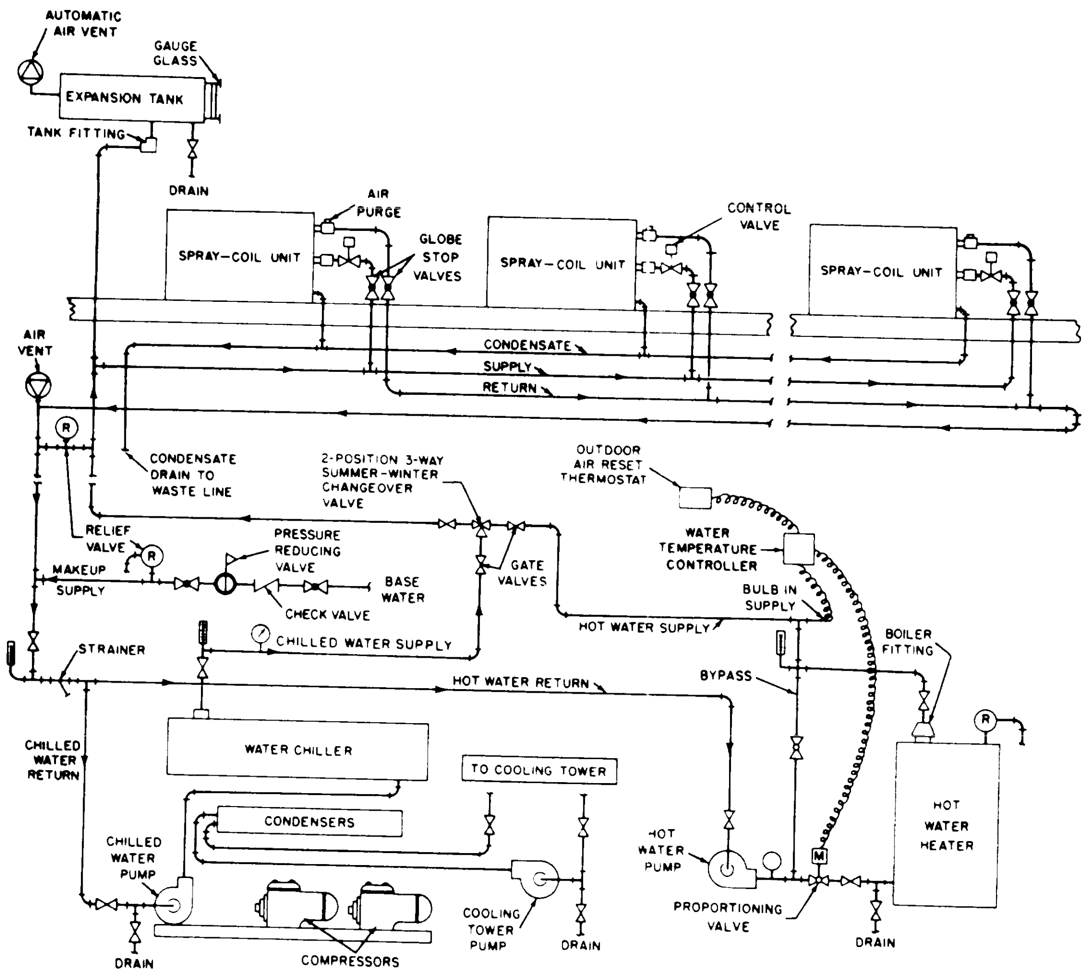

Figure 14-2.—Typical piping connections for a year-round air-conditioning system. 54.179

of an installation. Figure 14-3 shows the relationship between humidity, temperature and air movement.

SELECTION AND INSTALLATION OF RERIGERATION SYSTEMS

In a refrigeration system, the major consideration is the heat load calculation. There are five general factors that affect the refrigeration heat-load estimate required for a particular application.

Heat transmission load. This leakage occurs through walls, doors, ceilings, and floor space into the space being refrigerated.

Insulation factor. This is the rate of heat transfer that occurs through insulating material.

Air change load. This factor is determined by the frequency with which a door is opened and closed and the length of time a door is left open.

Product load factor. This is determined by the types of products being stored and product temperature at time of storage.

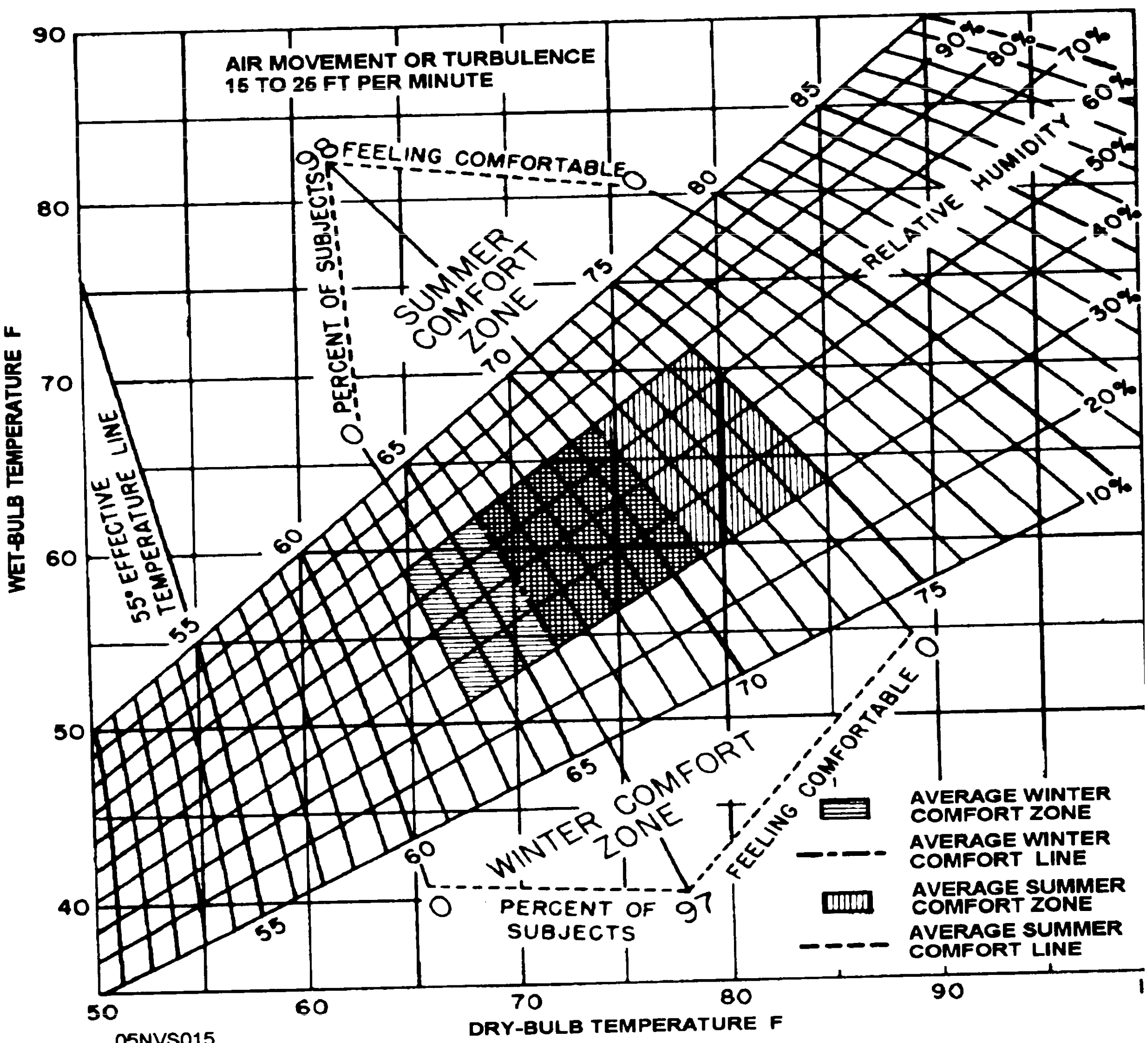

Figure 14-3.—Comfort zone chart.

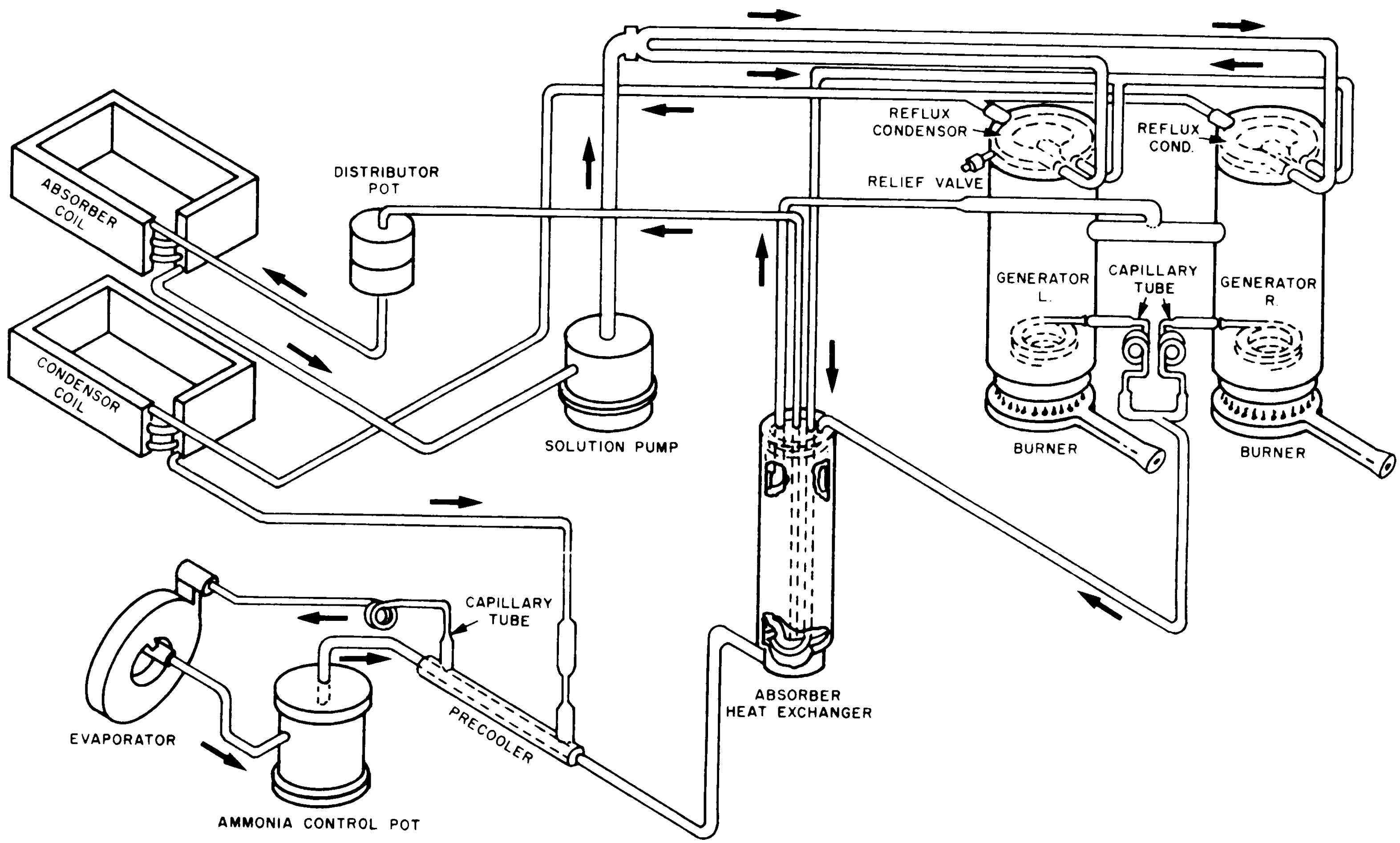

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Figure 14-4.—Absorption refrigeration cycle.

- Miscellaneous factor. This includes such factors as exposure to direct sunlight and ambient temperature surrounding the system.

There are several charts and graphs available that depict the relationship between the factors listed above. To do the job right, you must take into consideration the total effect of the factors before selecting a particular refrigeration system.

SPECIAL TYPES OF REFRIGERATION SYSTEMS

There are certain applications where an electrically powered refrigeration system cannot be used. This requires knowledge of special applications and selection of a refrigeration system that will work effective . The absorption and the expendable refrigeration systems are discussed in this section.

ABSORPTION REFRIGERATION SYSTEM

An absorption system uses either water, ammonia, or lithium bromide as the refrigerant. The system can range from very simple (small refrigerator) to complex (commercial freezer). This type of system is used in domestic and industrial refrigeration and air-conditioning applications. The absorption system is also used in recreational vehicles. Normally, these systems are identified by the type of heat source being used to power them, such as kerosene, natural gas, steam, or electricity. Because of the high pressure (400 psi), you should remember that welded steel tube construction must be used throughout the system. Also, because of the reaction between ammonia and copper or brass, you need a set of steel manifold gauges. Figure 14-4 shows an absorption.refrigeration cycle using ammonia as the refrigerant.

EXPENDABLE REFRIGERATION SYSTEM

An expendable refrigeration system. is for used in trucks, railroad cars, and shipping containers that transport perishable items. The three types of refrigerants presently being used in an expendable system are liquid nitrogen, carbon dioxide, and liquid helium. The evaporator system and the spray system are two types of expendable systems commonly used in the Navy, and they are discussed in this section

Evaporator Systems

In the expendable evaporator system, liquid refrigerant is stored in large metal insulated cylinders. These cylinders are normally located in the front of the cargo vehicle. Each cylinder is equipped with a temperature control to provide a temperature range of –20°F to 60°F.

The temperature control is connected to a temperature sensor. As the temperature rises, the switch operating the control valve opens and liquid refrigerant flows into the evaporator. The evaporator can be blower coils, plates, or eutectic plates. As it passes through the evaporator, the refrigerant vaporizes. This vapor is pushed through the evaporator by the pressure difference between the cylinder and the vent. When the selected temperature is attained, the refrigerant valve closes. The vapor that has been used is then discharged from the evaporator at about the same temperature as the air in the cargo vehicle. With this system, the refrigerant does not mix with air in the vehicle space. An example of the expendable evaporator system is shown in figure 14-5. This example shows two nitrogen cylinders located inside a truck body that are connected by a manifold to regulators and to temperature control solenoid valves. The vaporizing liquid nitrogen flows into the vaporizers or cold plates to refrigerate the true box.

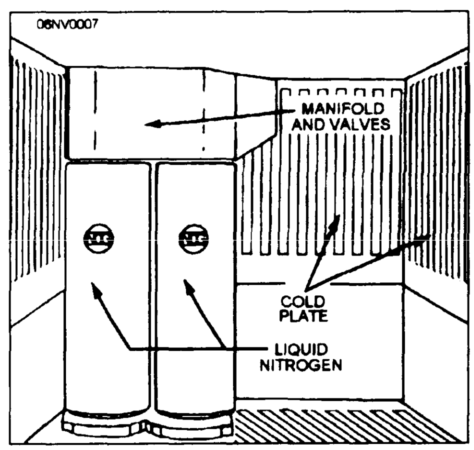

Figure 14-5.—Expendable evaporator refrigeration system.

Spray Systems

In the expendable refrigerant s ray system, liquid nitrogen or carbon dioxide is sprayed directly into the vehicle space that is to be cooled. This system. uses liquid containers, a control box, a fill box, spray headers. emergency switches. and safety vents.

The fill box is normally located on the front of the vehicle. It contains the valves, gauges, and connections that allow the liquid containers to be filled. The liquid containers are insulated cylinders similar to thermos bottles. The control box contains the valves, gauges, and thermostats that are necessary for safe release of the liquid to the spray headers. Once the liquid is received at the spray headers, the nozzles spray it into the vehicle. The remaining two components are primarily safety devices. These emergency interlock switches are attached to each door. Thus, whenever a door is opened, the system shuts down. The safety vent is a small trapdoor that vents air directly to the atmosphere whenever the air inside the truck box exceeds atmospheric pressure.

A benefit of this system is that liquid nitrogen or carbon dioxide replaces the oxygen inside the space being refrigerated. Therefore when fruits, vegetables, meats, and fish are being refrigerated, they are also preserved by the inert atmosphere.

A vehicle equipped with this type of system must display the following safety sign:

CAUTION: THE TEMPERATURE OF LIQUID NITROGEN, AS IT COMES FROM THE SPRAY NOZZLES, IS BELOW (0°F.

Liquid nitrogen will instantly freeze any part of the human body that it touches. Since liquid nitrogen can be dangerous, you should always inspect the refrigerated space before closing the doors. An expendable spray system for a refrigeration truck is shown in Figure 14-6. In this system, the liquid nitrogen is in an insulated container that is installed vertically inside the truck body. Another similar type of spray system with the refrigerant container mounted horizontal under the truck body is shown in figure 14-7.

THERMOELECTRIC REFRIGERATION SYSTEM

This type of system is used to move heat from one area to another by use of electrical energy. The electrical energy, rather than the refrigerant, serves as a "earner." The primary use of thermoelectric systems has been in portable refrigerators, water coolers, cooling of scientific apparatus used in space exploration, and in aircraft. The main advantage of this system is there are no moving parts. The system is compact, quiet, and requires little service.

MULTISTAGE REFRIGERATION SYSTEM

Multistage refrigeration systems are used where ultralow temperatures are required but cannot be obtained economical] through the use of a single-stage system. The reason for this is the compression ratios are too high to attain the temperatures required to evaporate and condense the vapor. There are two general types of -systems presently in use–cascade and multistage (compound.)

Cascade System

The cascade system has two separate refrigerant systems interconnected in such a way that the evaporator from the first unit cools the condenser of the second unit. This allows one of the units to be operated at a lower temperature and pessure than would otherwise be possible with the same type and size of single-stage system. It also allows two different refrigerants to be used, and it can produce temperatures as low as —250°F. Refer to figure 14-8. In this typical cascade system,

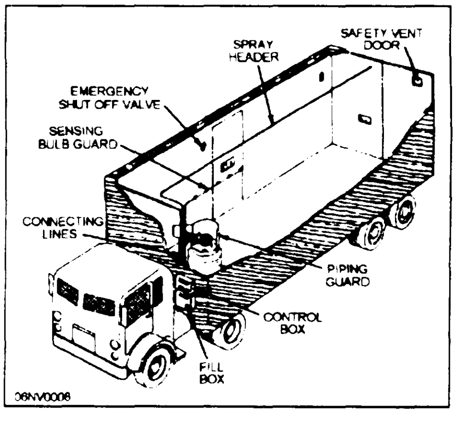

Figure 14-6.—An expandable spray System

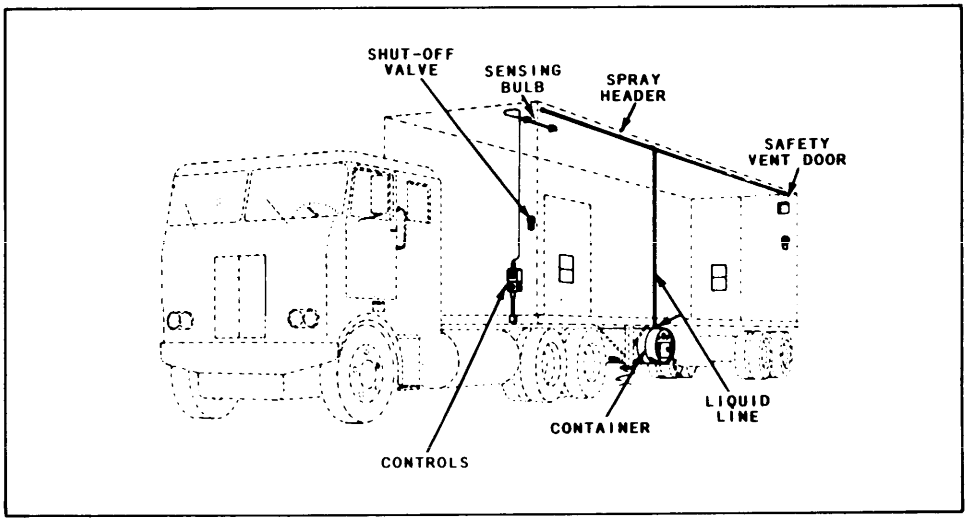

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Figure 14-7.—An expendable spray system.

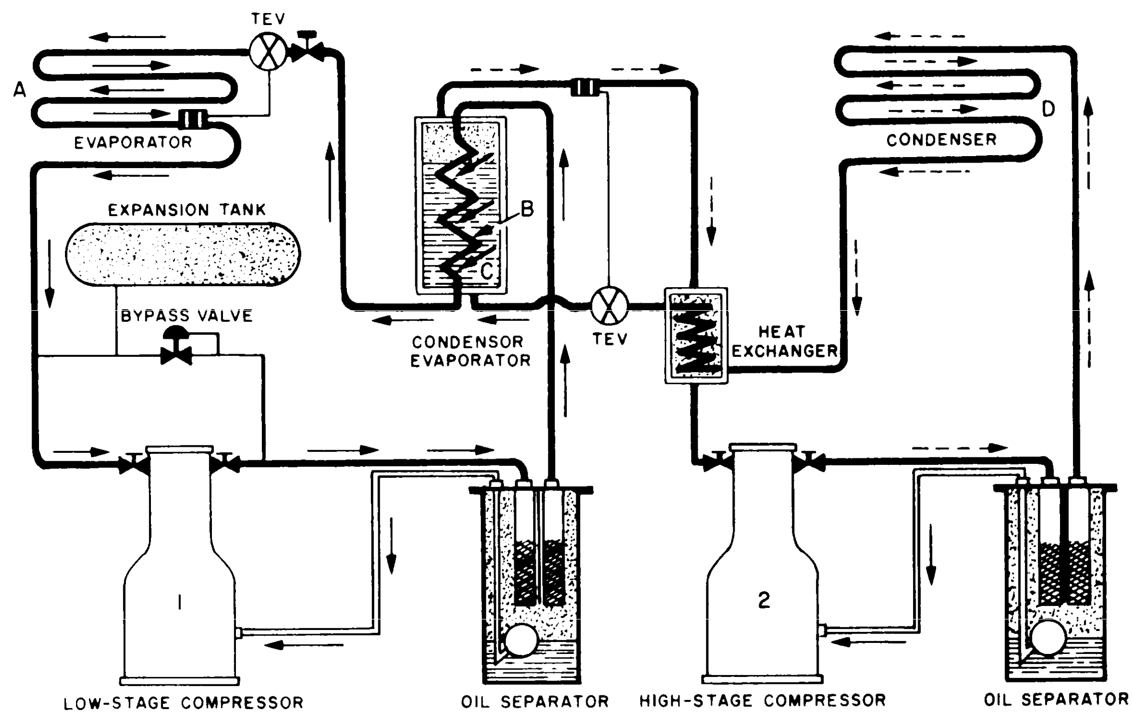

Figure 14-8.—Cascade refrigeration system.

condenser B of system 1 is being cooled by evaporator C of system 2. This arrangement enables ultralow temperatures in evaporator A of system 1. The condenser of system 2 is shown at point D in the figure. Two TEV refrigerant controls are also indicated in the figure. Notice the use of oil separators to minimize the circulation of oil.

Compound System

The compound system uses two or more compressers connected in series in the same refrigeration system. In this type of system the first stage compressor is the largest and for each succeeding stage the compressor gets smaller. This is because

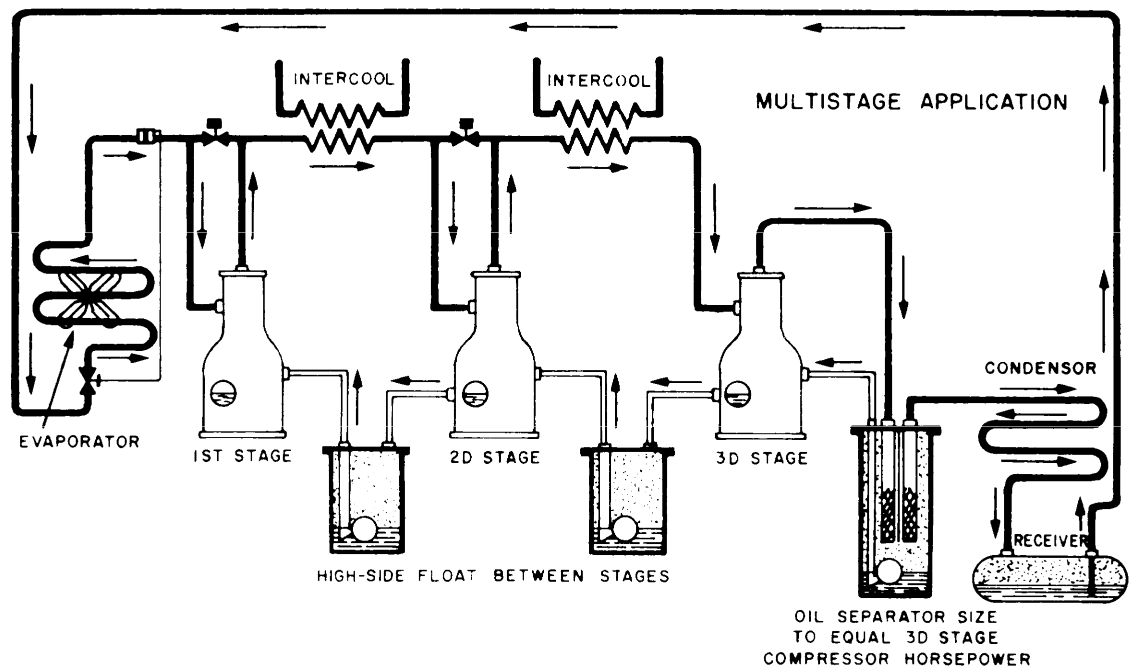

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Figure 14-9.—Multistage refrigerating system.

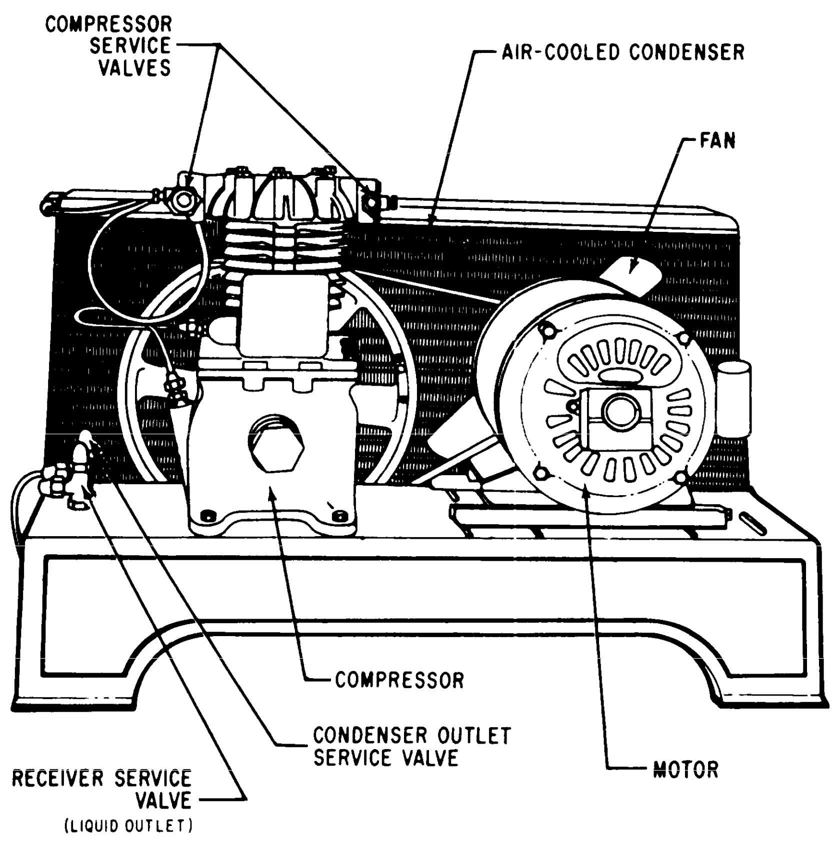

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Figure 14-10.—Air-cooled condenser mounted on a compressor unit.

as the refrigerant passes through each compressor, it becomes a more dense vapor. A two-stage compound system can attain a temperature of approximately –80°F. A three-stage system, like the one depicted in figure 14-9, can attain a temperature of –135°F efficiently. Compressor 1 pumps vapor into the intercooler and then into the intake of compressor 2. This operation is repeated between the second and third stages. In the third stage, the refrigerant vapor is further cooled and travels to the evaporator for specific cooling use.

MECHANICAL COMPONENT SELECTION

There are several mechanical components required in a refrigeration system. In this section, we discuss the four major components of a system and some equipment associated with the major components. These components include condensers, evaporators, compressors, refrigerant lines and piping, refrigerant capacity controls, receivers, and accumulators,

CONDENSERS

There are several condensers to be considered when making a selection for installation. They are air-cooled, water-cooled, shell and tube, shell and coil, tube within a tube, and evaporative condensers. Each type of condenser has its own unique application. Some determining factors include the size and the weight of the unit, weather conditions, location (city or rural), availability of electricity, and availability of water. For example, is electricity available in single phase or three phase? Is electricity economical or prohibitive? Water in some locations may be scarce, expensive, or contain chemicals that make it unsuitable for use. Local zoning laws should also be checked to ensure there are no restrictions as to use of electricity, water, or location of the unit. If you installed a unit on a roof, the roof load strength is very important. In some locations, the noise factor of an operating unit is an important consideration. With the rapid advances in technology, you should contact a manufacturer whenever possible to get the latest condenser design features available for a special-purpose installation. Figure 14-10 shows a typical installation of an air-cooled condenser mounted on a compressor unit. Figure 14-11 shows a cutaway view of a water-cooled condenser.

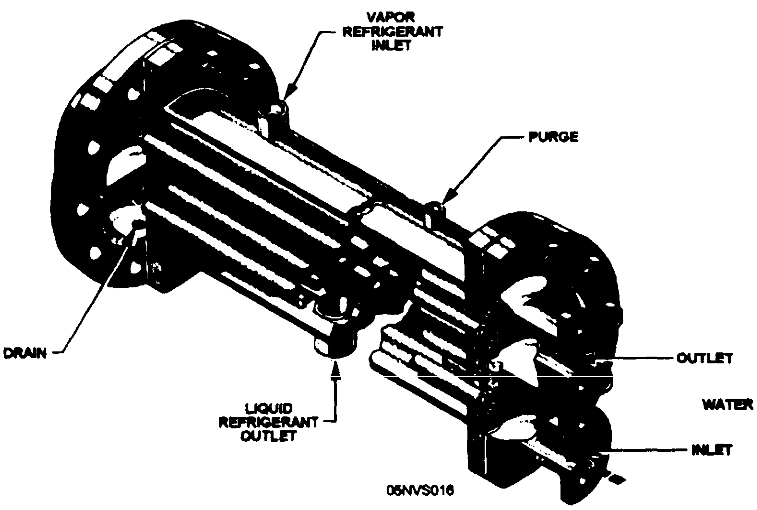

Figure 14-11.—Water-cooled condenser.

EVAPORATORS

There are almost as many different types of evaporators as there are applications. However, evaporators are divided into two general groups. The first group has evaporators that cool air that, in turn, cools the product. The second group has evaporators that cool a liquid such as brine solution that, in turn, cools the product. Normally, the proper evaporator comes with the unit (system) that you will be installing. However, there may be an occasion when you are designing a system. At this time, you will need to determine the requirements and select the proper evaporator from a manufacturer's catalog or manual. In figure 14-12 a blower-type evaporator is shown in a small space. The air enters the bottom of the evaporator, is cooled, and exits at the front of the unit. In figure 14-13, view A, a forced circulation evaporator is shown partially installed; view B shows the unit with the fan removed. A compact blower evaporator for use in low headroom fixtures is shown in figure 14-14. A vertical, flat-type blower evaporator designed for mounting behind either a window or a door frame is shown in figure 14-15. In the evaporator

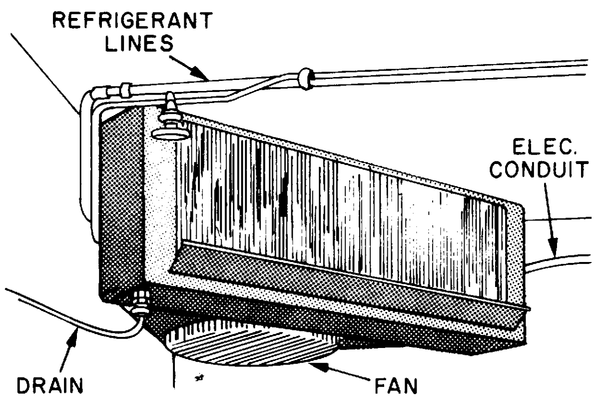

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Figure 14-12.—Blower-type evaporator.

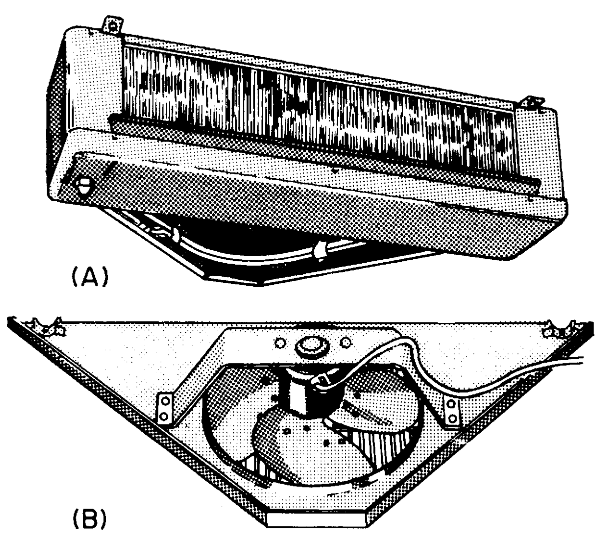

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Figure 14-13.—(A) Forced circulation evaporator partially installed; (B) fan unit removed.

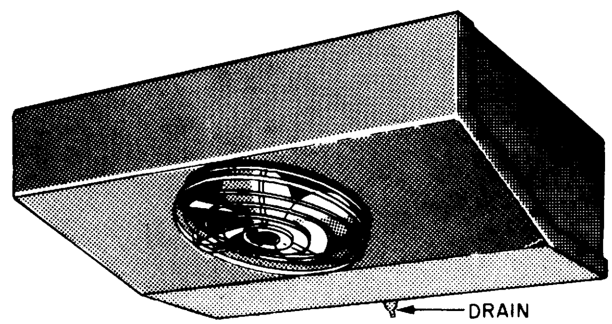

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Figure 14-14.—Compact blower evaporator.

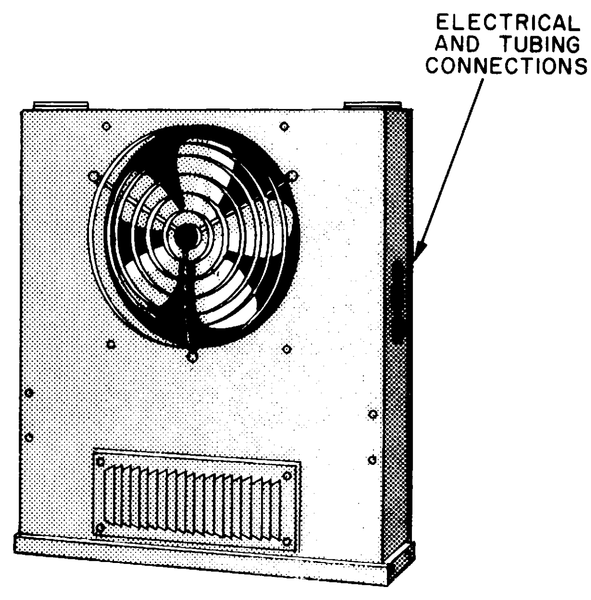

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Figure14-15.—Vertical, flat-type blower evaporator.

unit shown in 14-16, the motor drives two propeller-type fans and the cool air exits at both ends of the evaporator. Figure 14-17 shows a low-velocity blower evaporator. In this type of evaporator, the air enters at the two fan grills and exits on both sides. Figure 14-18 shows a low-temperature blower evaporator. The low-temperature evaporator has two axial-flow fans and an electric defrost.

COMPRESSORS

With present technology, the newer air-conditioning and refrigeration systems use reciprocating, rotary, screw, centrifugal, swash plate, and scroll compressors. There are many designs and models available for all types of applications. A typical hermetic compressor is shown in figure 14-19. For more in-depth information about compressors, you can refer to sources, such as *Modern Refrigeration and Air Conditioning* by Althouse/Turnquist/Bracciano.

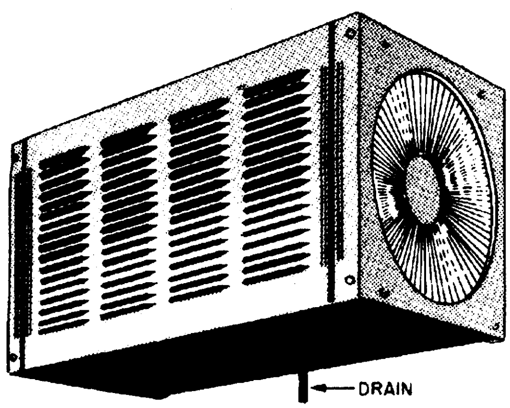

Figure 14-16.—Dual fan evaporator

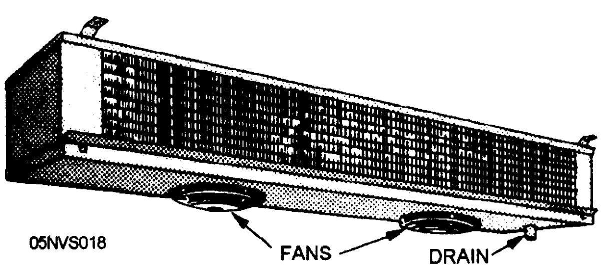

Figure 14-17.—Low-velocity blower evaporator.

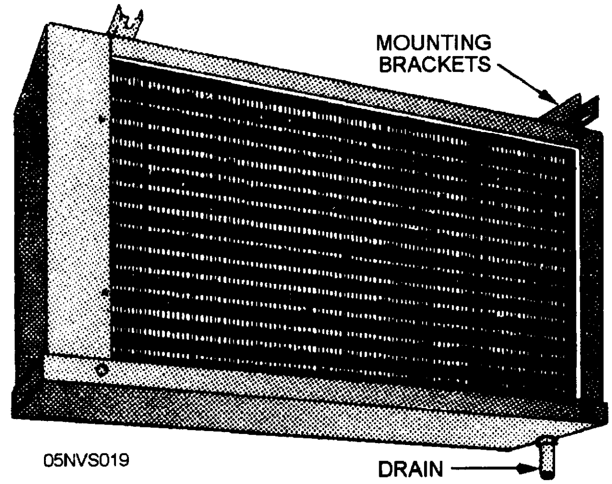

Figure 14-18.—Low-temperature blower evaporator.

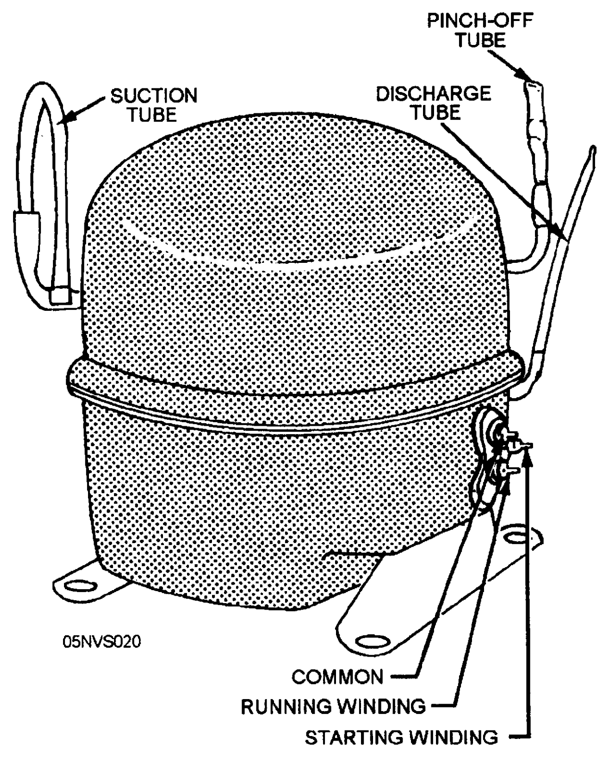

Figure 14-19.—Hermetic compressor.

THERMOSTATS

The thermostat is a control that responds to changes in temperature and directly or indirectly controls the temperature. There are many different designs of thermostats. Figure 14-20 shows a few of the common thermostats used in modem heating and cooling systems. Thermostats are of three types: heating, cooling, and dual (combined heating and cooling thermostat in one).

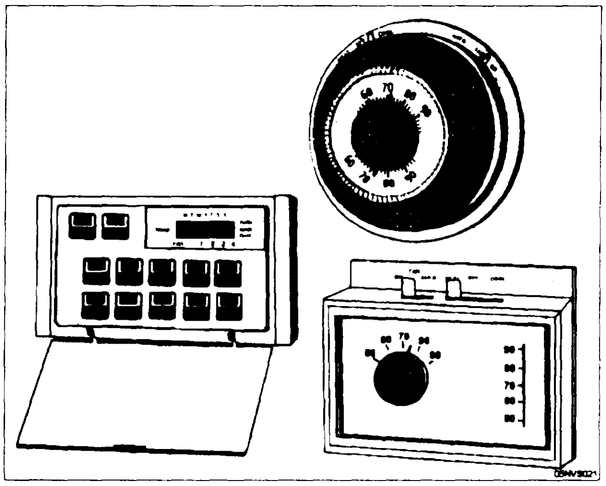

Figure 14-20.—Thermostats.

The common sensing element of a thermostat is bimetal. A bimetal sensing element simply uses two different types of metal, brass and invar, which have different expansion rates. Figure 14-20(A) depicts three common profiles of bimetals used in thermostats.

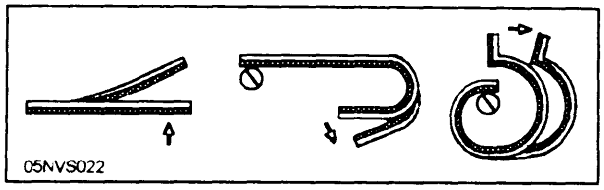

Figure 14-20(A).—Bimetal profiles.

The bimetal element in 14-20(B) has a set of contacts on one end. The top contact is fixed. When the temperature changes around the bimetal, the two contacts open or close.

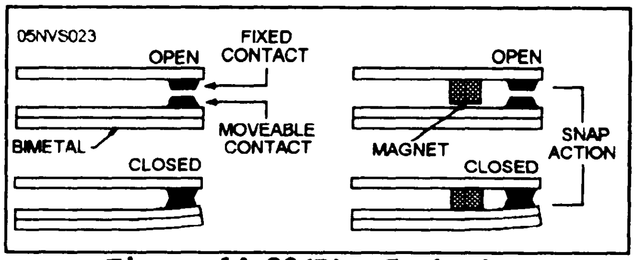

Figure 14-20(B).—Contacts.

When the contacts close, a path is created for current to flow. The snap action in the magnetic type makes the contacts close or open quickly. This eliminates any spark and extends the life of the contacts. Figure 14-20(C) shows enclosed contacts that use a bimetal element for movement and contacts or mercury for making contact between two electrodes.

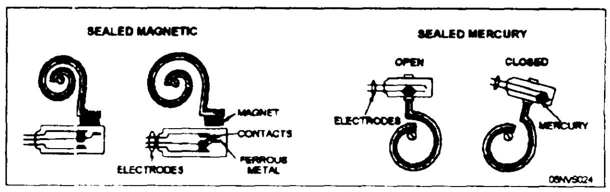

Figure 14-20(C).—Contacts.

The manufacturing engineers determine what type and design of thermostat should be installed in a particular system. Knowing and understanding the advantages and disadvantages of different types of thermostats will help you identify the type of thermostat being used in a system and enable you to troubleshoot an inoperative system efficiently.

Electrical room thermostats are in three categories: line voltage, low voltage, and millivoltage. Line-voltage thermostats are usually 115 volts. When line-voltage thermostats are installed, there is no need for lowering voltage with a transformer. However, line-voltage thermostats are dangerous for the users and the cost is higher. Normally line-voltage thermostats are located only in industrial commercial applications.

Low-voltage thermostats (24 volts) are not dangerous to the user. They are also more cost efficient than line-voltage models. The disadvantage of low-voltage thermostats is the extra requirements of wiring and additional components; they are less rugged than line-voltage thermostats.

The millivoltage thermostat operates at 750, 500, or 250 millivolts. This thermostat uses its own power source for operation and is not affected by power interruptions. The system requires only a small amount of wiring compared to other systems. However, this system is limited for use only in heating applications. The temperature control is less precise than other systems, wire length and size are critical, and the system requires a separate device to power a 24-volt control, or you must use a millivoltage control.

Anticipators

One component that enhances the operation of a thermostat is an anticipator. Anticipators are of two types-heating and cooling. The heating anticipator produces false heat in a thermostat to prevent extreme temperature changes within a space. The false heat created by resistance increases the thermostat rate of response. Basically, the thermostat receives false heat which shuts down the heating source before the thermostat reaches the desired temperature. This action reduces overshooting and is economically efficient. The heating source shuts off and the blower continues to run using the heat transferred from the surface of the furnace and ductwork. When adjusting a heating anticipator, you must set the anticipator resistance to match the current rating of the primary control.

The cooling anticipator adds false heat to the thermostat bimetal element the same way as a heating anticipator. Unlike the heating anticipator, cooling anticipators are not adjustable; they are sized by the manufacturer of the thermostat. The cooling anticipator is placed in parallel with the cooling contacts. By studying figure 14-20(D), you can see that the cooling anticipator is energized when the unit is in the OFF cycle (thermostat contacts open). The small amount of heat produced by the resistance heat closes the TC before the actual temperature in the space reaches the thermostat cut-in setting. This action allows the unit to start removing heat before the temperature in the space climbs above the desired temperature. When the cooling

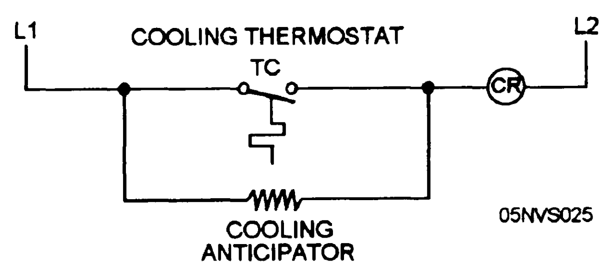

Figure 14-20(D).—Cooling anticipator.

thermostat contacts close, the current flow through the anticipator is insignificant because the contacts of the thermostat offer less resistance to current flow than the anticipator resistance, so the anticipator is de-energized.

REFRIGERANT LINES AND PIPING

Because of the progress made in this field, construction has become much simpler. Since precharged lines are in everyday use, the problems of installation are being eliminated. However, pay particular attention to neatness and cleanliness when you are installing support brackets (hangers) and insulation.

Figure 14-21 shows a schematic piping diagram of a typical commercial refrigeration system. This system has a roof-mounted air-cooled condenser and two motor compressors. Each motor compressor has a suction and a liquid header and is connected to six refrigerant lines. A detailed view of an oil separator installation is shown in figure 14-22.

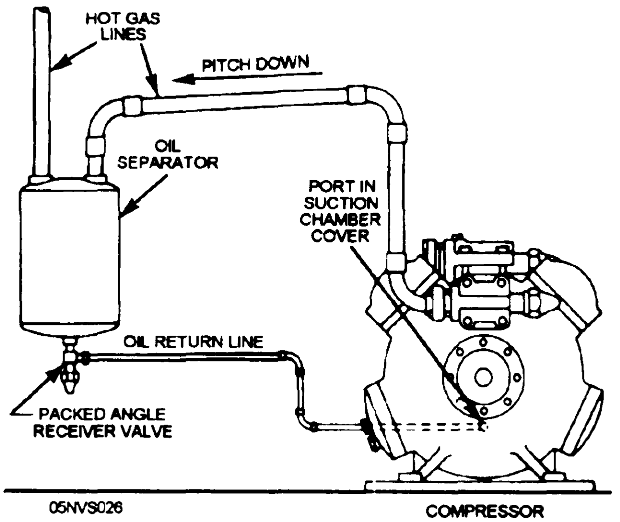

Figure 14-22.—Installation of an oil separator.

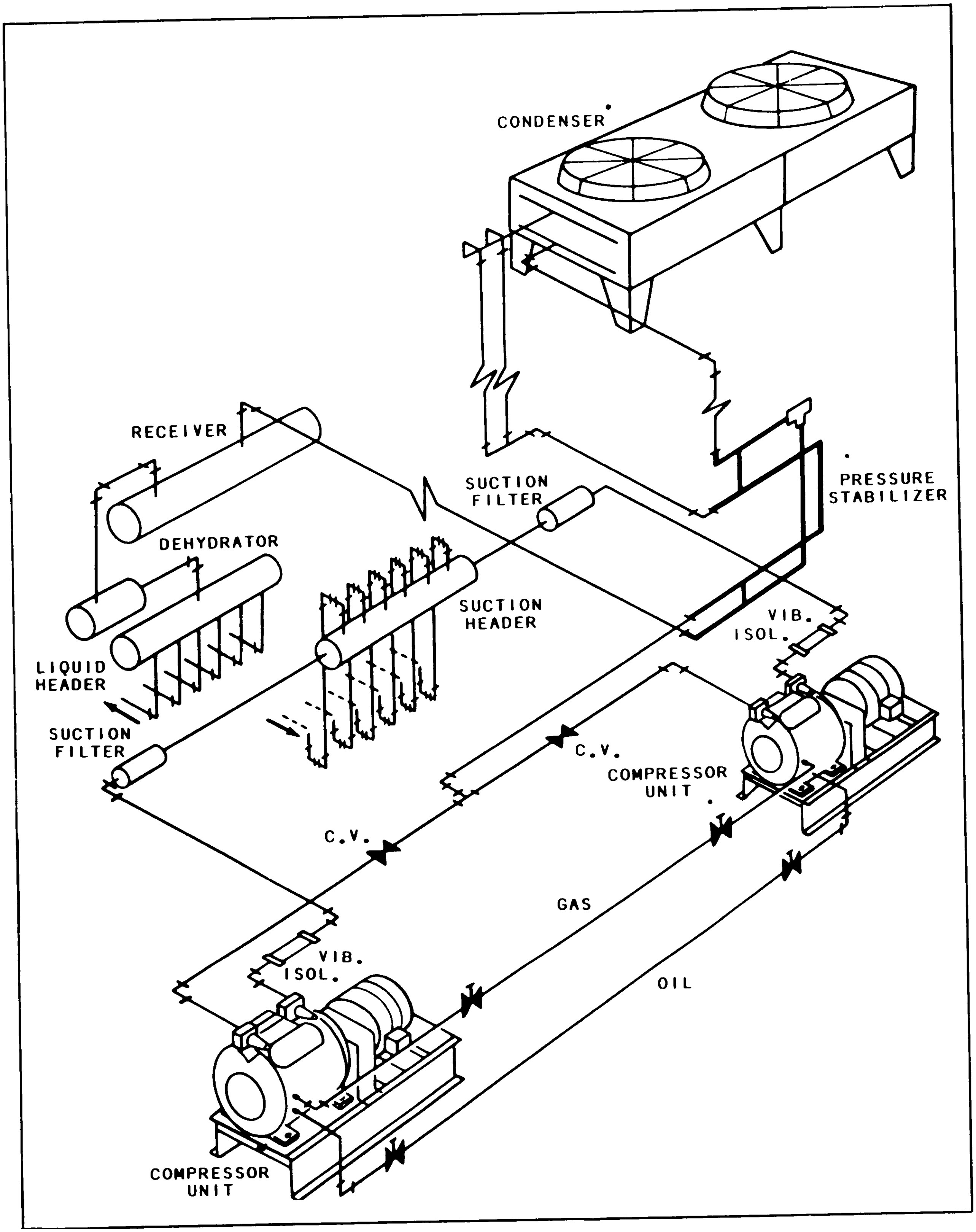

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Figure 14-21.—Schematic piping diagram for a commercial refrigeration system.

In a single-stage installation, one evaporator, one condensing unit, and any one of the five types of refrigerant controls will work. However, in a multistage installation (fig. 14-9) with one condenser, only two types of controls can be used. There are very few lmw-side float systems in actual operation, but you should be aware that there are some units that still use this control. Thermostatic expansion valves are the most commonly used, and on large capacity units, they usually operate a pilot valve that, in turn, operates a larger valve.

The biggest problem associated with capacity controls is using one of the wrong size. When ordering replacements and when making repairs, you should always ensure that the control markings are appropriate for the intended system. Also, ensure the replacement part being ordered is compatible with the type of refrigerant being used in the system.

Automatic Expansion Valve

The automatic expansion valve (AEV) maintains a constant pressure inthe evaporator. Looking at figure 14-22(A), there are five pressures that affect the operation of the AEV. The pressures are p_1 (atmospheric pressure), p_2 (evaporator pressure), p_3 (liquid line pressure), S_1 (adjustable spring pressure), and S_2 (fixed spring pressure). To adjust the valve, turn the adjusting screw until the desired pressure is obtained in the evaporator. Automatic expansion valves are installed on systems that have a relatively constant load. Primarily, the AEV is used on domestic refrigerators and small water coolers.

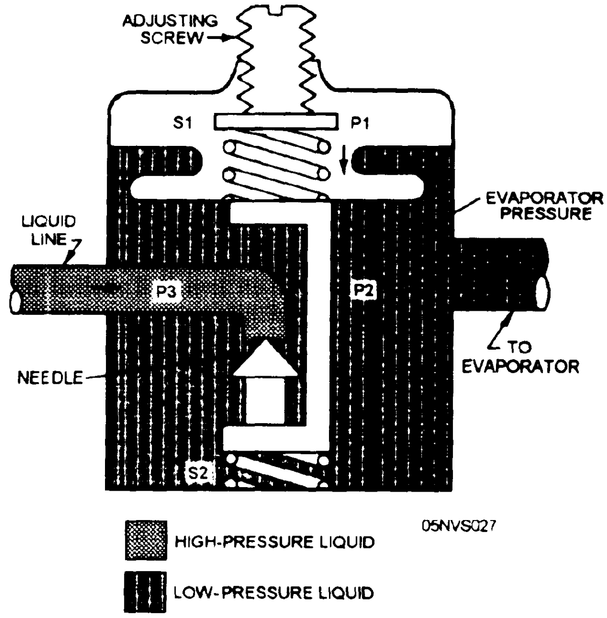


Figure 14-22(A).—Automatic expansion valve.

Thermal Expansion Valve

The thermal expansion valve (TEV) is the most widely used expansion device. The TEV controls the flow of refrigerant to maintain a constant superheat in the tail coil of an evaporator. Referring to figure 14-22(B), there are three pressures that affect the operation of this valve. They are p_1 (bulb pressure), p_2 (evaporator pressure), and p_3 (spring pressure).

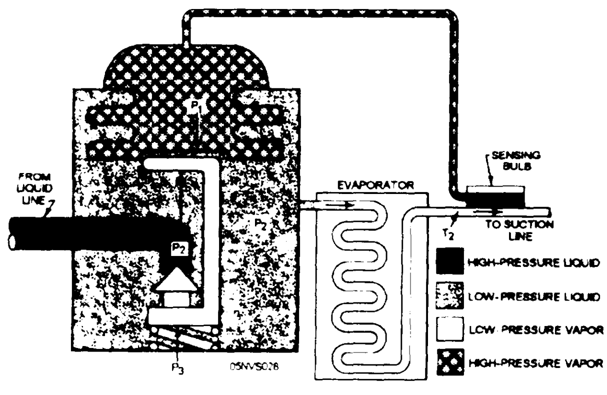


Figure 14-22(B).—Themal expansion valve.

When the pressure of p_1 is higher than the combined pressure of p_2 and p_3, the valve opens. This valve is equalized internally because the evaporator pressure is sensed through an intemal port in the valve. Figure 14-22(C) provides another view showing how a TEV is equalized internally. When a TEV is used on a large evaporator or an evaporator with a pressure drop of 6 to 7 pounds across the evaporator, the valve will prematurely cause hunting (valve fluctuates toward opening and closing). In the case of valve hunting, install a TEV equipped with an external equalizer line. Figure 14-22(D) shows the TEV installed with an external equalizer line. The external equalizer line compensates for a pressure drop from the inlet of the evaporator to the end of the tail coil and eliminates valve hunting. During installation of an equalizer line, ensure that it is located downstream from the sensing bulb.

Air-conditioning refrigeration units come equipped with a metering device that the manufacturer has engineered for the system. You should **never** change the recommended type of metering device for a system without consulting the manufacturer.

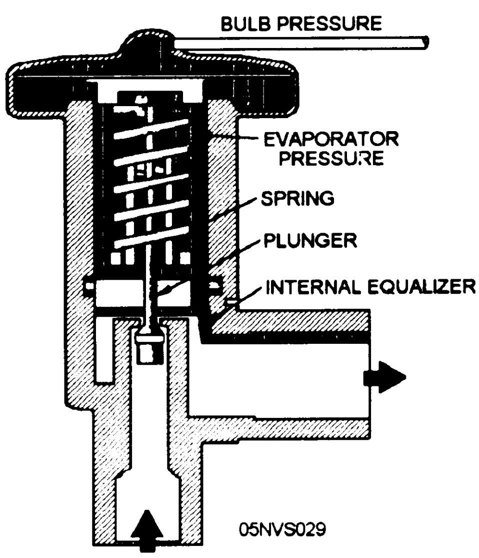


Figure 14-22(C).—Thermal expansion valve.

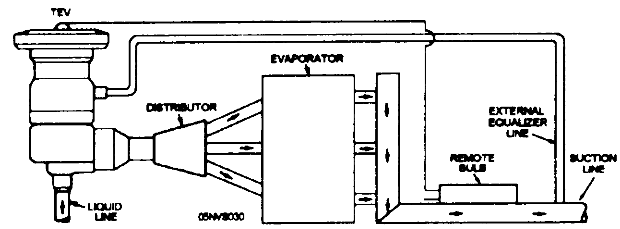


Figure 14-22(D).—Externally equalized TEV.

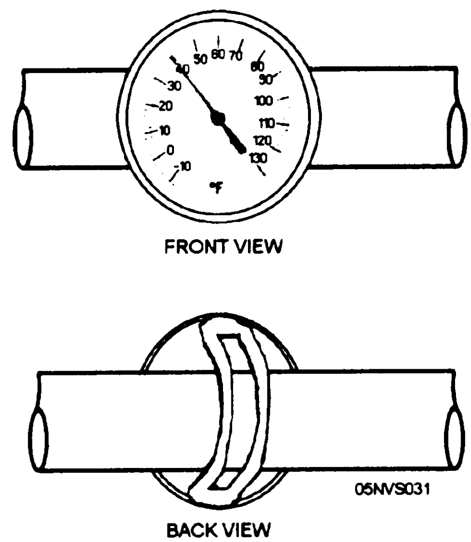


Figure 14-22(B).—Dial thermometer.

TEV Adjustment

Most TEVs are adjusted at a predetermined superheat setting and tested at the factory before they are shipped. If you need a different superheat setting, follow the steps in table 14-1(A).

Table 14-1(A).—Determining Superheat

STEP	ACTION
1.	Obtain the temperature of the suction line at the point where the TEV sensing bulb is attached. a. Take the temperature reading with a dial thermometer similar to the one shown in figure 14-20(E), or use some other temperature measuring device that senses surface temperatures accurately.
2.	Obtain the suction pressure inside the piping at the location of the remote sensing bulb. a. If the valve is externally equalized, you can place a gauge in the external equalizer line. This is the most accurate method. b. The alternate method is to read the manifold pressure gauges at the compressor and add the estimated pressure drop through the suction line between the bulb and compressor. The sum of the two pressures provides approximate pressure at the location of the remote bulb.
3.	Convert the pressure you received in step 2 into saturated evaporator pressure. a. Use a pressure temperature chart. When using the chart, ensure that you are looking at the proper refrigerant.
4.	Simply subtract the temperature in step 3 from the temperature in step 1. This is superheat.

Note: When adjusting the expansion valve, turn the adjusting stem no more than one full turn and wait approximately 15-30 minutes for the system to balance out. Once the system is balanced, recheck the superheat setting by following the steps in table 14-1(A).

RECEIVERS AND ACCUMULATORS

The receiver is a storage tank for liquid refrigerant. When a refrigeration system is equipped with a receiver, you can close the outlet valve (king valve) and pump refrigerant into the receiver. This enables you to store the refrigerant while you work on the unit. Additionally, when a unit is equipped with a receiver, the quantity of refrigerant in the system is less critical than a unit not so equipped. Figure 14-23 shows the location of a receiver installed in a system. This is a commercial system with an air-cooled condenser, a thermostatic expansion valve, and a V type of reciprocating compressor.

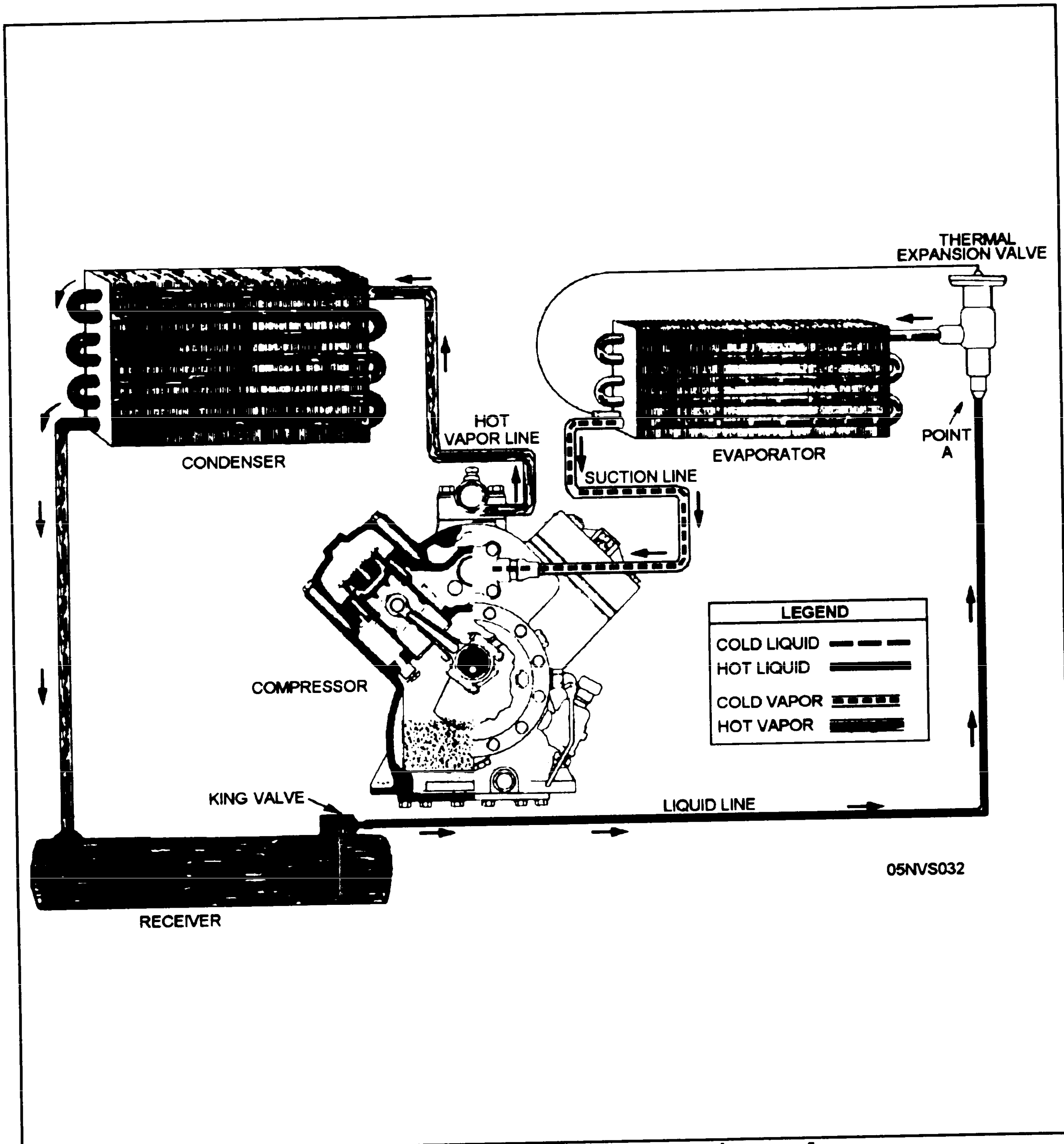


Figure 14-23.—Receiver in refrigeration cycle.

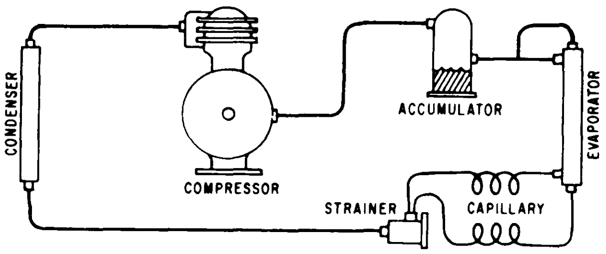
The accumulator is located inside the refrigeration cabinet and acts as a safety device. As a safety device it prevents the flow of liquid refrigerant into the suction line and the compressor. This is because liquid refrigerant causes considerable knocking and damage to the compressor. Figure 14-24 shows the location of an accumulator in a system.

SINGLE-PHASE HERMETIC MOTORS

Basically, there are four types of single-phase motors used in hermetic assemblies: the split-phase; the capacitor-start, induction-run; the capacitor-start, capacitor-run; and the permanent split-phase. Each motor is discussed in this section.

SPLIT-PHASE

The split-phase motor is used generally on condensing units of 1/10-, 1/6-, and 1/4-horsepower



54.301

Figure 14-24.—Accumulator location.

capillary tube systems. It has a low starting torque and contains both a starting winding and a running winding. A disconnect device is required for the starting winding when the motor reaches sufficient speed to operate on the running winding. Figure 14-25 is a schematic wiring diagram of a split-phase motor circuit.

CAPACITOR-START, INDUCTION-RUN

This motor is similar to the split-phase type except that a starting capacitor is connected in series with the starting winding to provide higher starting torque. Figure 14-26 is a schematic diagram illustrating this type of motor. A device is also required to disconnect the starting winding when the motor reaches rated speed. This motor is commonly used on commercial systems up to three-fourths horsepower.

CAPACITOR-START, CAPACITOR-RUN

Two capacitors are used with the capacitor-start, capacitor-run motor: a starting capacitor and a running capacitor. The capacitors are in parallel with each other and in series with the starting winding. Figure 14-27 is a schematic diagram illustrating this type of motor circuit. The two capacitors turn the motor power surges into two-phase power when the motor is started. At approximately two-thirds rated speed, the starting capacitor part of the circuit is disconnected by a start relay device. Only the running capacitor remains in the circuit. This type of motor has a

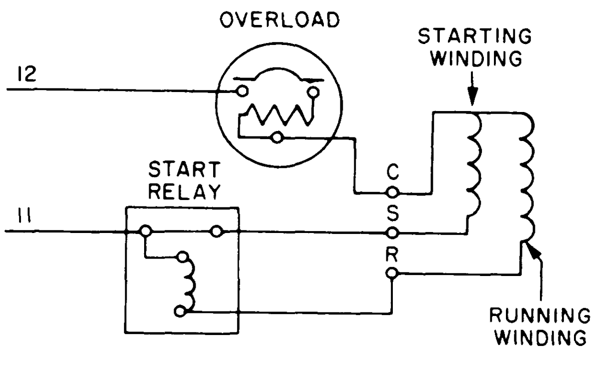


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Figure 14-25.—Schematic wiring diagram of a split-phase motor circuit.

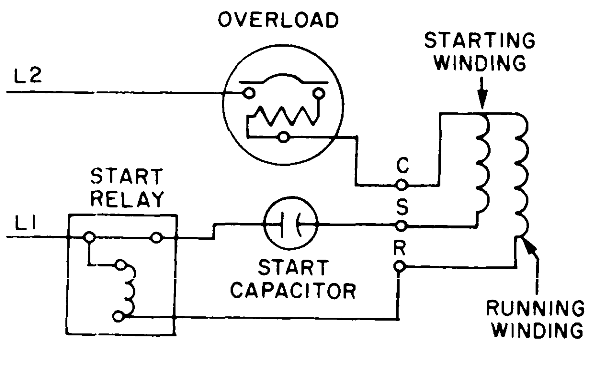

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Figure 14-26.—Schematic wiring diagram of a capacitor-start induction-run motor.

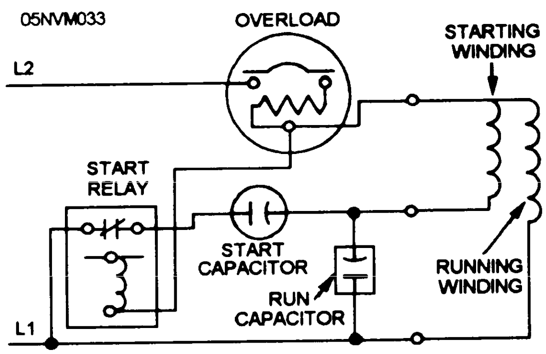


Figure 14-27.—Schematic wiring diagram of a capacitor-start capacitor-run motor.

high starting torque and is used with hermetic systems up to 5 horsepower.

PERMANENT SPLIT-PHASE

The permanent split-phase motor has limited starting torque and is used basically with capillary tube air-conditioning equipment, such as window units. Capillary systems permit high-side and low-side pressure equalization when the compressor is not operating. A run capacitor is wired in series with the starting winding. Both the starting winding and the run capacitor remain in the circuit during operation. No start relay or start capacitor is needed. Figure 14-28 is a schematic wiring diagram of the circuits used in this type of motor.

SPLIT-PHASE HERMETIC MOTOR WINDINGS AND TERMINALS

Split-phase motors used in hermetic refrigeration and air-conditioning applications are designed to start under load. These split-phase and capacitor motors use two sets of spiral windings: a starting winding and a running winding. The two sets of windings differ in their impedance and in their positions in the stator slots.

The starting winding has high resistance and small reactance, whereas the running winding has low resistance and high reactance. Reactance is the opposition to the flow of alternating current by inductance and capacitance. The running winding has many turns of large wire and is placed in the bottom of the stator slots. The starting winding is wound of small, high resistance wire and is placed on top of the running winding. Both windings are connected internally at one end to provide a common lead, and when starting, both are energized in parallel. The currents are out of phase with each other and their combined efforts produce a rotating field that starts the motor.

Figure 14-29 shows the starting and running windings of a two-pole motor in their 90-degree out-of-phase positions.

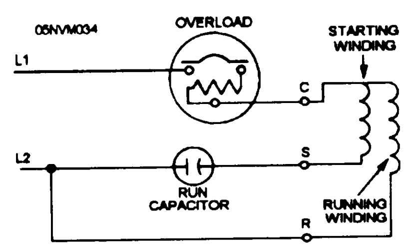


Figure 14-28.—Schematic wiring diagram of a permanent split-phase motor.

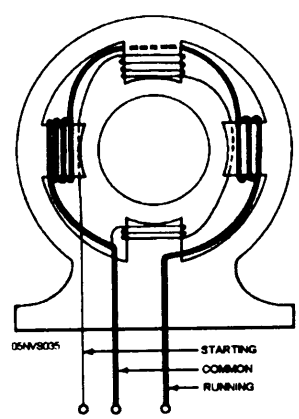


Figure 14-29.—View of a two-pole motor having starting and running windings.

Hermetic motors have three electrical terminals connected through an insulated seal to the motor windings inside the dome. Refer to figure 14-30. Troubleshooting procedures require that these terminals be identified with respect to the winding connected to each. The terminals must be identified as the START TERMINAL, the RUN TERMINAL, and the COMMON TERMINAL. Some manufacturers mark the S-, R-, and C-terminals for start, run, and common, respectively; other manufacturers use different designations.

The terminals can always be identified by using a low-range ohmmeter following the procedure below:

- Disconnect all power to the terminals, discharge capacitor where necessary, remove the wires connected to the terminals, and mark the wires so they can be reconnected properly.

- Clean terminals to provide a good connection.

- Using the ohmmeter, find the two terminals across which the greatest resistance occurs. The remaining terminal is the C-terminal. The resistance between the S- and R-terminals is highest because both are being measured in a series circuit.

- Identify the S-terminal by placing one meter lead on the C-terminal and then checking the other two terminals to determine which one has the greatest resistance. The S-terminal (starting winding) has windings with many turns of small wire, and therefore has the greatest resistance. The remaining terminal is the connection of the running winding.

- Always mark the terminals so they can be identified later.

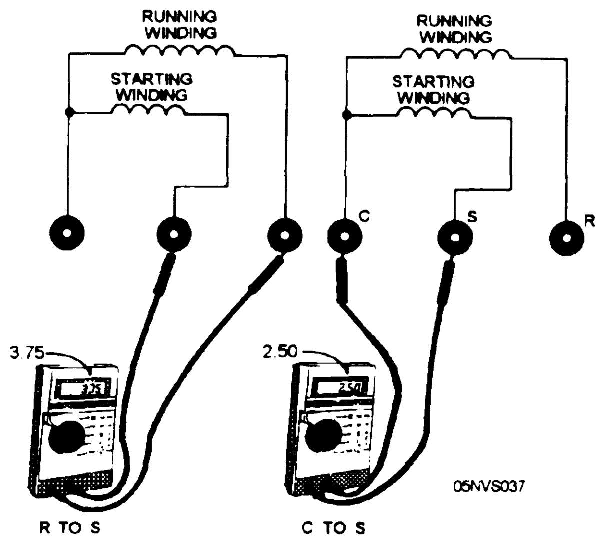


Figure 14-30. —Identifying motor terminals using an ohmmeter.

TROUBLESHOOTING ELECTRICAL SYSTEMS

Electrical troubleshooting techniques are used on refrigeration and air-conditioning equipment. Electrical troubleshooting is done by a process of elimination. You should begin by checking the most obvious trouble and gradually progress to the more remote possibilities. As a Utilitiesman you cannot troubleshoot an electrical system for an air-conditioner or refrigeration unit unless you understand the function of each component in a system. When you can observe a unit operating and detect what is not functioning properly, you can identify the circuit or circuits that are having trouble. At this point you must be able to test each of the components within a circuit that is not functioning properly. Of course to do all of this. you must also be able to read and interpret electrical diagrams, understand loads, determine paths, and perform electrical testing procedures.

CIRCUITS

There are two basic types of circuits–load and control. The LOAD CIRCUIT consists of a circuit that contains a load and all of the wiring that provides line voltage directly to the load, such as compressor motor, fan motor, solenoid valves, lights, or any device that consumes current (other than the movement of an electrical switch). The second type of circuit is the CONTROL CIRCUIT. Simply stated, a control circuit contains controls that either open or close a path that operates a load device. Each load has a control circuit. Control circuits consist of thermostats, pressure switches, overload protectors, and all of the wiring in the control circuit.

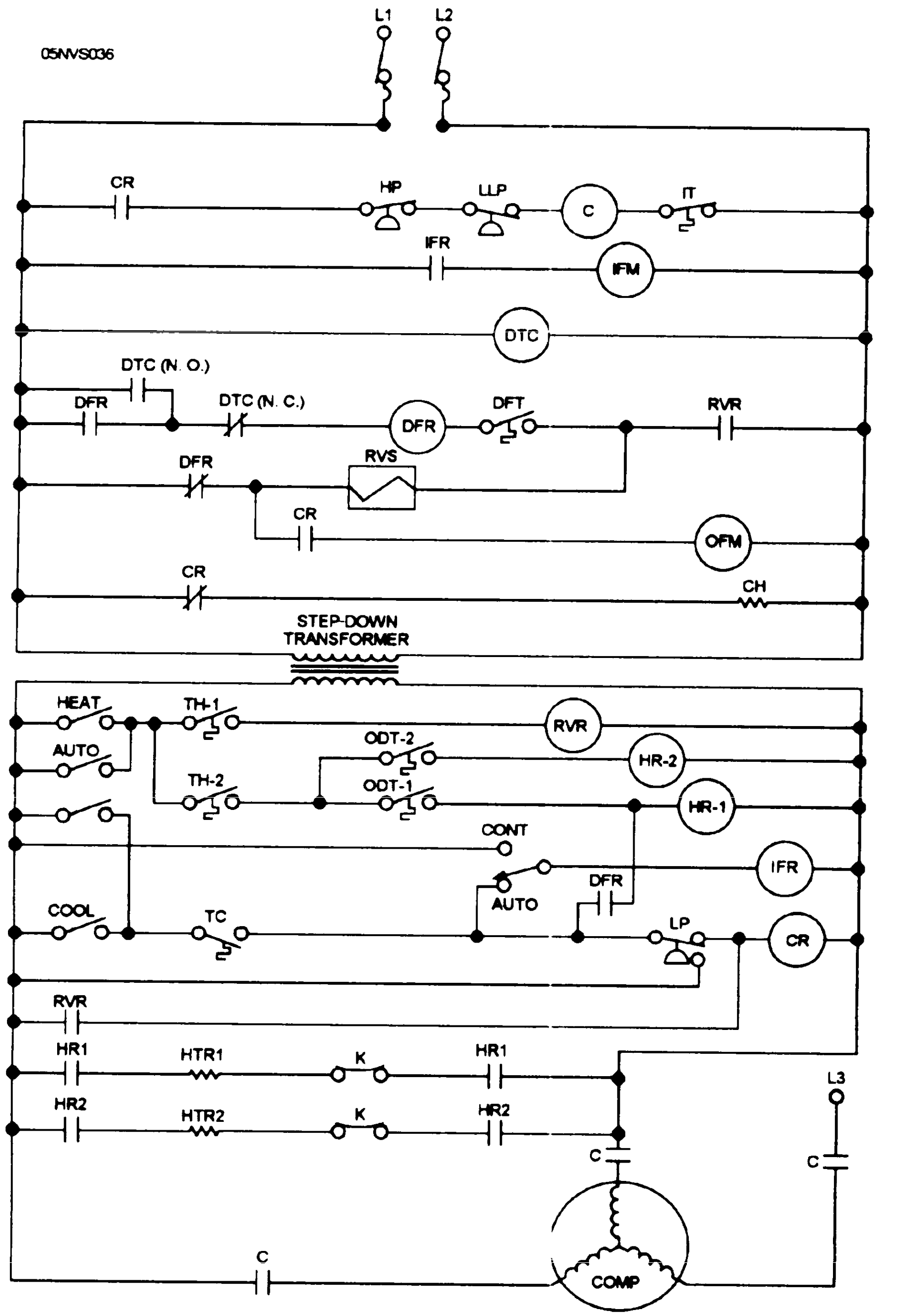
LOADS AND CONTROL CIRCUITS

Air-conditioning and refrigeration units normally have two fan motors and a compressor. Thesr components are considered load. A load is any device that consumes electrical energy. Most loads convert electrical energy into another type of energy to create some type of work. For example, electrical energy is converted to magnetism within a motor to make the motor run.

All loads have some type of control so they can be turned on, off, or regulated. These controls are located in a control circuit. The circuit is made up of controls and paths wiring. Controls and control circuits consume no electrical energy; they simply provide a path for electrical energy to flow, thus indirectly controlling the operation of various types of loads. Figure 14-29(A) shows an electrical schematic wiring diagram of a heat pump. At first glance the diagram appears complex, but after studying the diagram briefly and looking at one circuit at a time, the diagram becomes easy to follow and understand. An example is as follows: Look at the first circuit in figure 14-29(A). The circuit contains a control relay contact (CR), high-pressure switch (HP), liquid line pressure switch (LLP), compressor contactor (C), and an internal thermostat (IT). This is a complete circuit. The CR is simply a set of contacts and falls in the category of a path; the contacts are either open or closed. The HP and LLP are both pressure switches and are controls in this circuit; the pressure switches are either open or closed. The C is the compressor contactor. Actually this is a magnetic coil located within a contactor that simply closes all of the contacts in the diagram that are labeled C. The IT (internal thermostat) is located inside the compressor and opens when there is a temperature rise. The only load in this circuit is the compressor contactor because it is a current consuming device. Now, look at figure 14-29(A) and see if you can find the load in the second circuit. The load is the indoor fan motor (IFM) because it is a current consuming device. The IFR contact only provides a path for the current to energize the indoor fan motor.

TESTING CIRCUITS

To troubleshoot an inoperative or improperly operating unit electrically, you must be able to use a process of elimination systematically and use a multimeter effectively. Remembering and understanding a few simple rules will enable you to use a multimeter to locate a faulty electrical component or control. The first circuit in figure 14-29(A) is used as an insert to illustrate the different meter readings you will encounter when troubleshooting an electrical system. Refer to the insert next to the applicable troubleshooting procedure.



C — COMPRESSOR CONTACTOR
CR — CONTROL RELAY
HP — HIGH PRESSURE SWITCH
LLP — LIQUID LINE PRESSURE SWITCH
IT — INTERNAL THERMOSTAT
IFM — INDOOR FAN MOTOR

IFR — INDOOR FAN RELAY
OFM — OUTDOOR FAN MOTOR
DTC — DEFROST TIME CLOCK
DFR — DEFROST RELAY
DFT — DEFROST THERMOSTAT
RVS — REVERSING VALVE SOLENOID

TH — THERMOSTAT HEATING
ODT — OUTDOOR THERMOSTAT
RVR — REVERSING VALVE RELAY
HR — HEATING RELAY
TC — THERMOSTAT COOLING
LP — LOW PRESSURE SWITCH

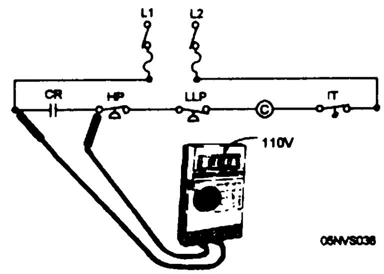
Figure 14-29(A).—Heat pump schematic.

Voltage Readings

To begin, set your multimeter to voltage; ensure the power is on and all wires are connected to the component being tested. The four important troubleshooting procedures that apply to reading voltage are as follows:

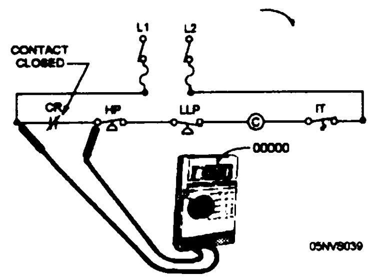
1. Place the meter probes are on a path. If there is a voltage reading, the path is open.

- Place one meter probe on the left side of the CR contact and the other probe on the left side of the HP switch.
If you obtain a voltage reading, this indicates that either the path is open or the contacts are open.



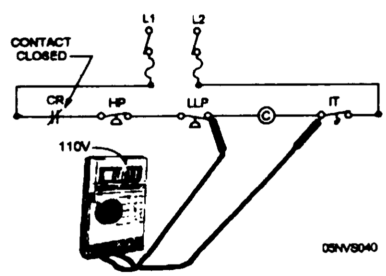
2. Place the meter probes on a path. If there is no-voltage reading, the path is closed.

- Place one meter probe on the left side of the CR contact and the other probe on the left side of the HP switch. If you obtain no voltage reading, the path is closed.



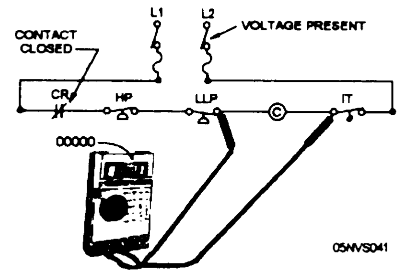
3. Place the meter probes across a load. If a voltage reading is obtained, the load is recieving current. When the load is NOT operating, you should check for a grounded winding and for winding resistance.

- Place one meter probe on the right side of the LLP switch and the other probe on the left side of IT. If you obtain a voltage reading, the compressor contactor is energized and the compressor should be running.



4. Place the meter probes across a load. If there is no-voltage reading, you have an inoperative load. Replace the load.

- Place one meter probe on the right side of the LLP switch and the other probe on the left side of the IT. If there is no voltage reading, replace the load.

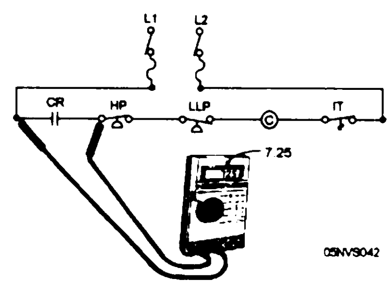


Continuity Readings

To perform an ohmmeter continuity test, set your multimeter to resistance; disconnect the power and remove the wires from the component being tested. Perform a continuity test as follows:

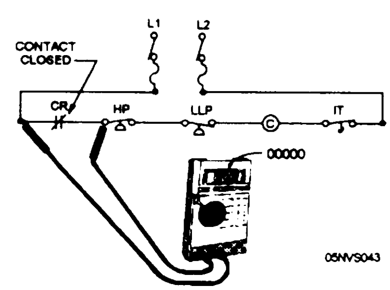
1. Place the meter probes across a path. If a reading is obtained, it indicates an open path.

- Place one meter probe on the left side of the CR contact and the other probe on the left side of the HP switch. If you obtain a reading, the path is open.



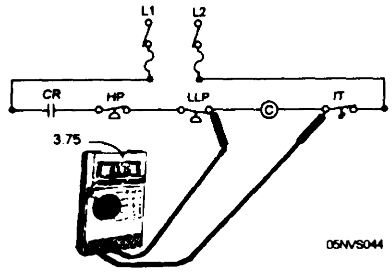
2. Place the meter probes across a path. If a zero reading is obtained, the path is closed.

- Place one meter probe on the left side of the CR contact and the other probe on the left side of the HP switch. With the CR contact closed, you should obtain a zero reading. This indicates the path is closed.



3. Place the meter probes across a load. You should obtain a reading.

● Place one meter probe on the right side of the LLP and the other probe on the left side of the IT. You should obtain a reading. If you obtain no reading, replace the load.



To further increase your understanding of electrical troubleshooting, review the rules you have just read using a different method. The flow charts in figure 14-30(A), and (B) review electrical troubleshooting with a digital multimeter. To use a multimeter effectively and troubleshoot an A/C & R unit electrically, you must not only know the information provided here but also practice by testing circuits. Always remember to respect electricity. Whenever possible, perform your electrical troubleshooting with the power OFF using continuity checks.

TESTING MOTOR WINDINGS

If, during the procedure for identifying motor terminals, the ohmmeter displays a blank readout during any test, there is probably a defective winding. A defective winding may be classified as an OPEN winding or a SHORTED winding. The display will be zero if the winding is GROUNDED. Test equipment and procedures applicable to faulty windings are discussed below.

OPEN WINDINGS

Open windings can occur in the starting winding, the running winding, or both. An open winding is the result of a burned-out or grounded fault or simply a break somewhere in the lead or winding that prevents the current from completing the circuit. A motor with an open winding does not start. If only one winding is open, the motor hums, but if both windings are open, no sound is emitted nor current consumed. Open windings can be checked by an ohmmeter, a voltmeter, or a test light.

Ohmmeter Continuity Test Procedure

The procedure for making an ohmmeter continuity test is shown in figure 14-31 and outlined below.

● Turn the power OFF, discharge all capacitors, and remove the wires from the C-, S-, and R-terminals of the motor.

● With the ohmmeter set on the lowest scale, check the resistance from C to R, C to S, and R to S.

Table 14-30.—Electrical Troubleshooting Loads

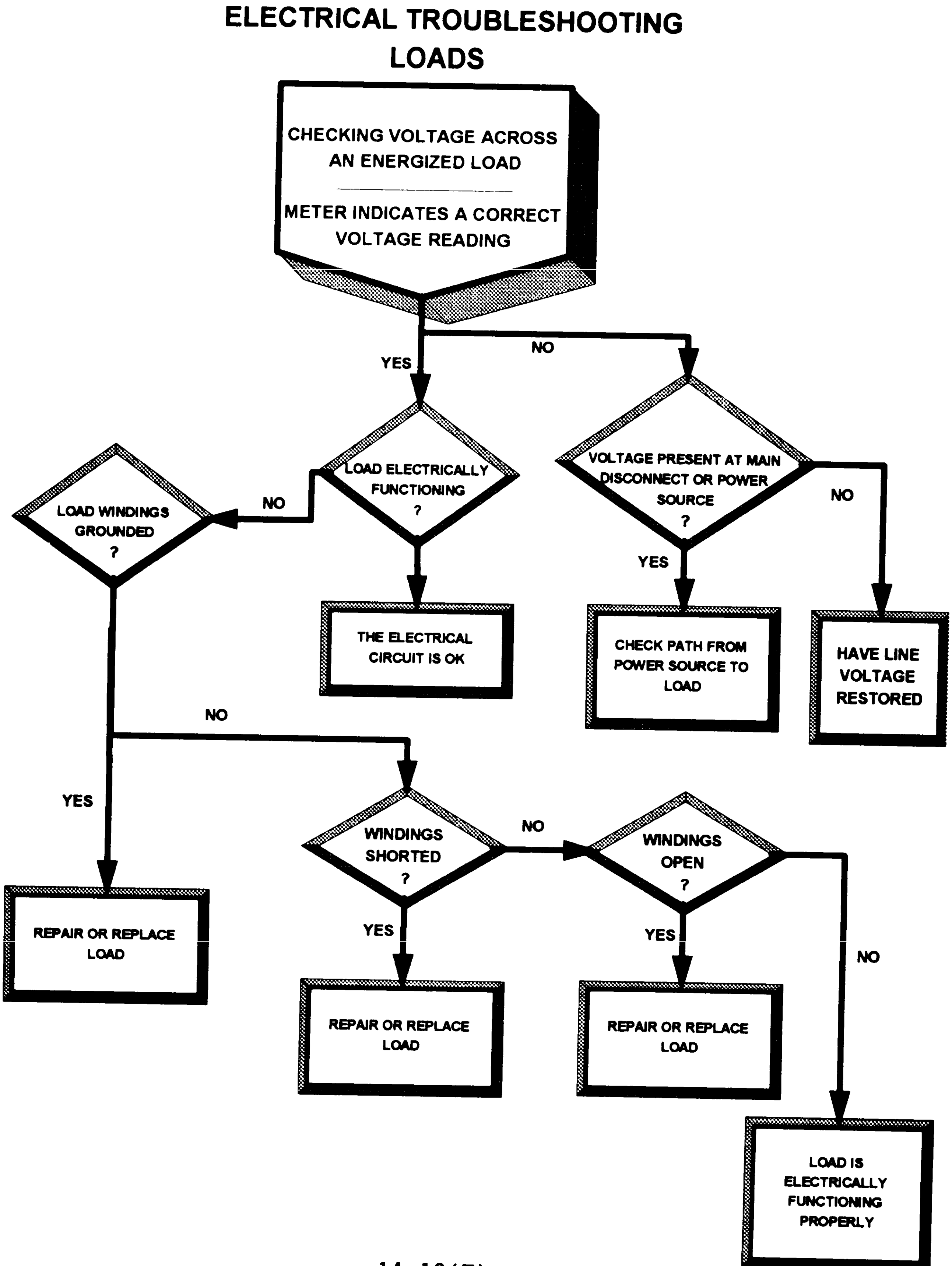
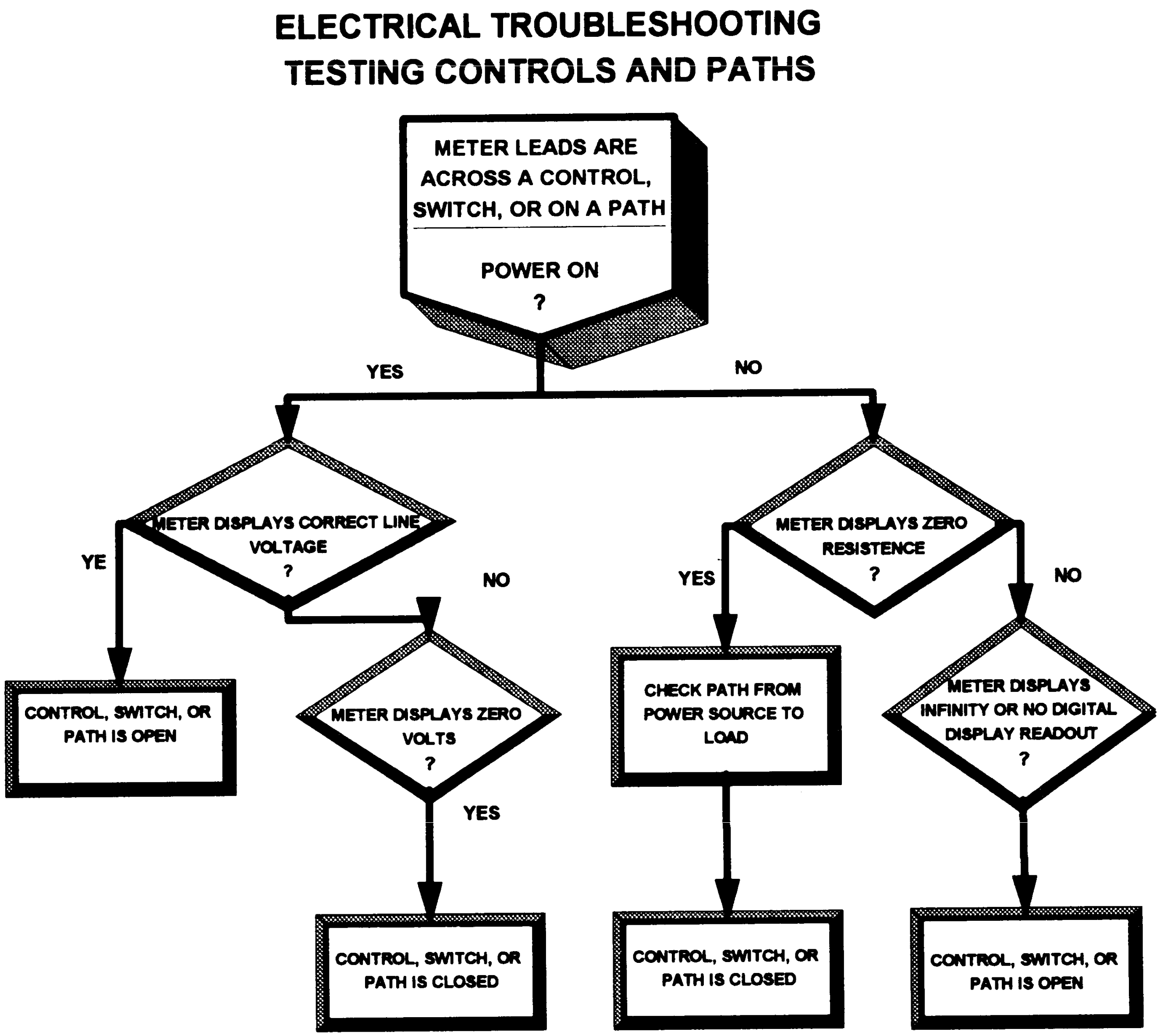


Table 14-30(B).—Testlng Controls and Paths



TABLES 14-30(A) AND 14-30(B) DO NOT COVER EVERY ELECTRICAL TROUBLESHOOTING PROCEDURE YOU WILL INCUR. THE TABLES ARE PRESENTED TO HELP YOU UNDERSTAND ELECTRICAL TROUBLESHOOTING.

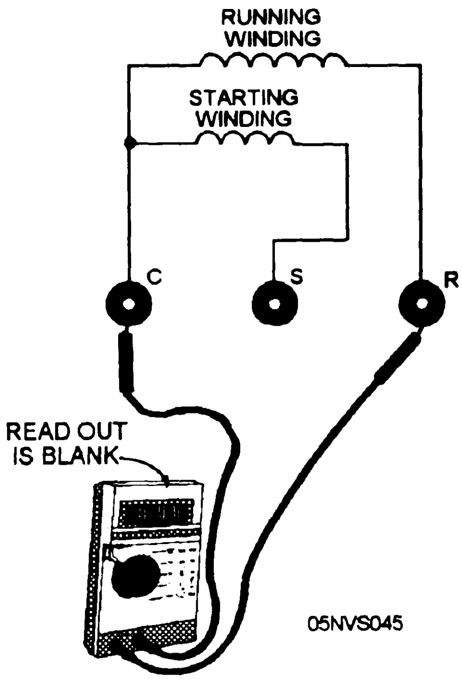


Figure 14-31.—Testing for an open winding with a ohmmeter.

- Watch the digital readout in the meter as the check is made. Each reading should appear to be approximately 0 ohms, since winding resistance is usually less than 10 ohms. If, during the check, the resistance digital display remains blank (infinity), an open or break exists.

Voltmeter Test Procedure

The procedure for carrying out a voltmeter test is as follows:

- Ensure the power is on and all wires are properly connected to motor terminals.
- With the voltmeter set on the proper scale, place the leads across the R- and C-terminals.
- Read the voltmeter.If the motor shows line voltage, the motor is energized and should be operating. The connections are similar to that shown in figure 14-31.

Test Lamp Continuity Check Procedure

The procedure for conducting a test lamp continuity check is as follows:

- A simple test lamp consisting of a power circuit plug, two flexible insulated wires with clip leads, and a 25-watt socket with a bulb is used. Figure 14-32 shows the test lamp procedure.
- Ensure the power is OFF, discharge all capacitors, and remove the motor terminal wires.
- Make a continuity test through both windings by attaching clips across the C-terminal, then do the other terminals one at a time. Now plug the test lamp into a receptacle. If the bulb fails to light, there is an open winding.

SHORTED WINDINGS

In an electric motor the winding turns lie side by side with only the insulating varnish separating one loop from another. When one loop of the copper wire contacts another, the

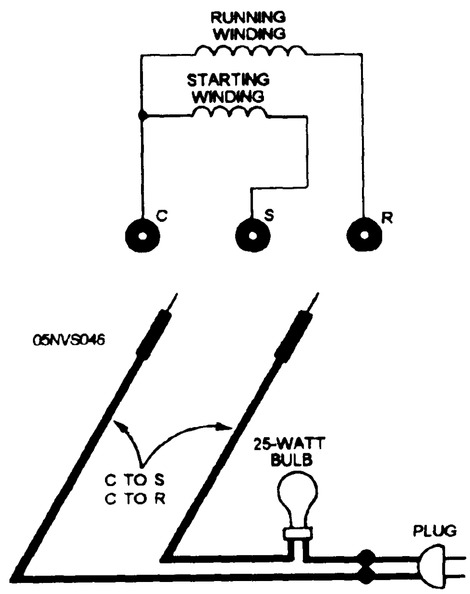


Figure 14-32.—Testing for an open winding with a test lamp.

winding is short. The pulling effect of the shorted portion of the winding is lost. This, in turn, places more load on the active winding, causing the motor to draw higher voltage and amperage with a concurrent increase in winding temperature. In this condition the motor either fails to start, or it starts and continues to run, finally causing the overload protector to open. The fuses may also blow. The result is likely to be a burnout where the insulating varnish deteriorates from excessive heat. Ultimately a ground or short occurs.

An ohmmeter can be used to check windings for shorts. For most applications a low-range meter with a scale graduated in tenths of ohms between 0 and 2 ohms is best. However, to check motors throughout the sizes normally encountered in hermetic motor-compressor units, a range of 0 to 25 ohms is necessary. The meter is used to measure resistance of the windings. The readings are compared with design resistances. A short is shown when measured resistance is less than design resistance. The ohmmeter connections are the same as those shown in figure 14-30.

Often manufacturer's data is not available and the design resistances are not known. Table 14-1 lists the approximate resistances for fractional horsepower single-phase motors. The following guidelines may also be helpful:

1. The starting winding of low-starting torque motors usually has a resistance of about seven to eight times that of the running winding.

2. The starting winding resistance of high- starting torque motors is usually three to four times that of the running winding.

GROUNDED WINDINGS

A ground is the result of an electrical conductor in contact, either directly or indirectly, with the motor frame or the metal shell of the unit. Either the starting winding, the running winding, or both can be affected. The ground is either one of low resistance or one of high resistance. A low-resistance ground is indicated when fuses blow repeatedly and the motor fails to start. A high-resistance ground is shown by an occasional blown fuse, but more often, by the opening of the overload protector.

Table 14-1.—Approximate Resistances for Fractional Horsepower Motor Windings

HP	Running Winding	Starting Winding
1/8	4.7Ω	18Ω
1/6	2.7Ω	17Ω
1/5	2.3Ω	14Ω
1/4	1.7Ω	17Ω

Three methods of testing windings for grounds are the ohmmeter continuity test, the test lamp continuity check, and the resistance measurement with a megohmmeter. The procedure to follow in making each of these tests is provided below.

Ohmmeter Continuity Test (Low-Resistance) Procedure

To perform an ohmmeter continuity test, proceed as follows:

- Disconnect the power and remove the wires from the motor terminals.
- Scrape off paint and clean a spot on the motor-compressor shell for testing.

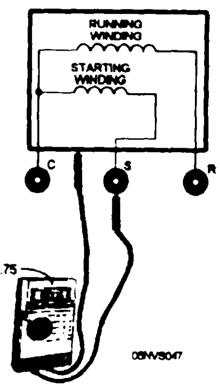


Figure 14-33.—Testing windings for ground with an ohmmeter.

● With the ohmmeter set on its highest scale, test for continuity between the terminals and the shell. This procedure is shown in figure 14-33. If continuity exists between the terminals and the shell, there is a ground.

Test Lamp Continuity Check (Low-Resistance) Procedure

The procedure for conducting a test lamp continuity check is as follows:

● Disconnect the power and remove the wires from the motor terminals.

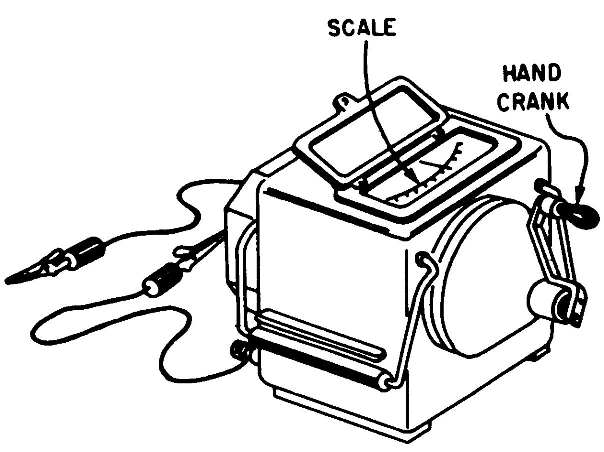
● Ensure the lamp is connected in the hot side of the line. Plug the test lamp into a receptacle.

● Connect the hot-line probe to a motor winding terminal.

● Touch the free probe to the cleaned spot on the shell. Ensure that a good connection is made. If the light illuminates, there is a grounded winding.

Megohmmeter (High-Resistance) Test Procedure

The megohmmeter (megger) consists of an indicating movement for which current is supplied by a small hand-driven generator. Figure 14-34 illustrates a typical megger used by the SEABEES.



236.261

Figure 14-34.—A typical megohmmeter (megger).

Two leads are supplied, one of which is marked Earth or Ground.

The procedure for making the megohmmeter (high-resistance) test is as follows:

● Disconnect power and remove the wires from the motor terminals.

● Place the megger probe marked Earth or Ground on the motor or compressor frame. Ensure there is a good metal-to-metal contact.

● Place the free probe on terminals C, S, and R in sequence. If any reading of low resistance is obtained, the motor is grounded.

You should always refer to the manufacturer's instructions when using a megger. It is also a good idea to request assistance from a Construction Electrician.

ELECTRICAL CIRCUIT COMPONENTS

Electrical components in hermetic motor compressor circuits that give trouble include starting relays, overload protectors, and capacitors. It is essential that a refrigeration and air-conditioning service member be able to identify these components and test them using the proper equipment and procedures.

STARTING RELAYS

Basically there are three types of starting relays in use. They are the current relay (magnetic type), the voltage relay (magnetic type), and the thermal relay (hot-wire type). In the hermetic motor control circuit, a starting relay allows electricity to flow through the starting winding until the motor reaches two-thirds to three-fourths of its rated speed. At this time, about 3 to 4 seconds after starting, it disconnects the starting circuit.

Current Relay

A current relay is an electromagnet, similar to a solenoid valve, that employs a weight and spring to hold the contacts open when the circuit is idle. In operation the instantaneous surge of starting current actuates the magnetic coil, causing the start winding contacts to close. This closure allows starting current to the winding;

after about 3 to 4 seconds, the motor reaches its rated speed and the current decreases, causing the relay contact to open and disconnect the winding. Current relays are ideal for use with split-phase, induction-run motors.

Figure 14-35 is a schematic diagram of a current relay motor starting circuit.

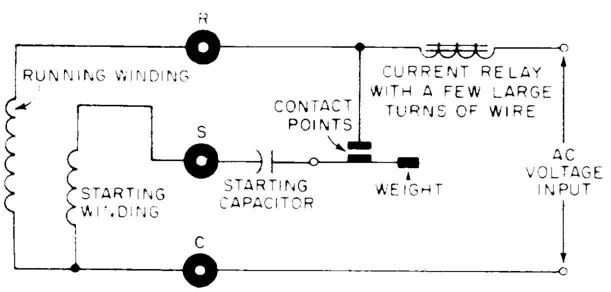
Voltage Relay

A voltage relay looks much like a current relay; however, it differs in operation. It operates on increased voltage as the motor reaches rated speed, and, unlike the current relay, the contacts remain closed during the off cycle. When the motor is first turned on, it draws heavy current and the voltage drop across the starting winding is low. As the motor picks up speed, there is less and less load; therefore, more and more voltage is induced into the winding. At about three-fourths rated speed the voltage is high enough to cause the relay coil to pull the contacts open and disconnect the winding. Voltage relays are used with capacitor-start motors. Figure 14-36 is a schematic diagram of voltage relay motor starting circuit.

Thermal Relay

A thermal relay is commonly known as a hot-wire relay. It is available in at least two different basic designs and is supplied by several manufacturers. All thermal relays operate on the theory that electrical energy can be turned into heat energy and that, when the temperature of a metal is increased, the metal expands. Thermal relays, like current and voltage relays, operate the starting winding circuit. In addition, the thermal relay controls the running winding circuit, if for any reason the circuit draws excessive current.

The device consists of a specially calibrated wire made from a material with high oxidation resistance and two sets of contacts, all of which are integrally attached to form the relay. Figure 14-37 illustrates a typical thermal relay motor starting circuit. The contacts are controlled by the hot wire, either through the use of heat-absorbing



87.249

Figure 14-35.—Schematic diagram of a current relay motor starting circuit.

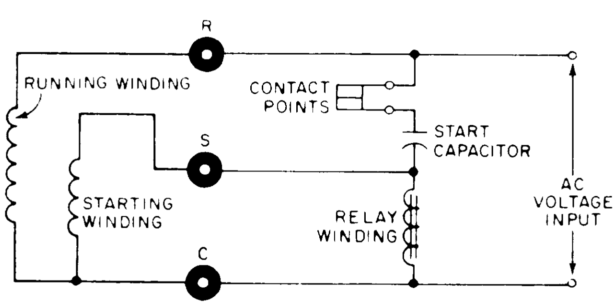


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Figure 14-36.—Schematic diagram of a voltage relay motor starting circuit.

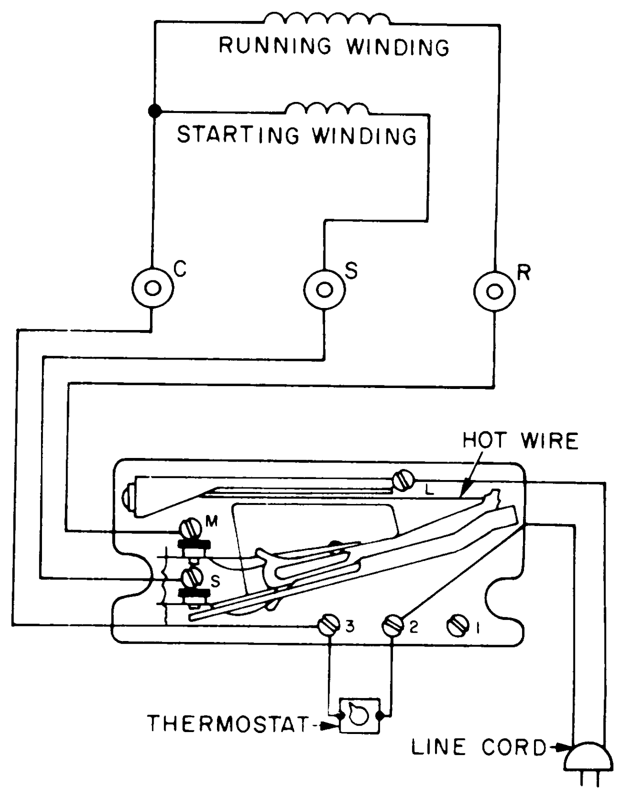

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Figure 14-37.—A typical thermal relay motor starting circuit.

bimetallic metal strips, or by its expansion of the hot wire, depending on the design of the relay.

OVERLOAD PROTECTORS

Essentially, an overload protector is a heat sensitive device much like a circuit breaker. When current in the circuit increases above normal, the added current heats a bimetallic strip that bends and opens a pair of contacts. The opening of the contacts disconnects the motor-running circuit and the motor stops. This prevents damage to the compressor motor when troubles occur, such as a defective starting relay, an open starting capacitor, or high-head pressure. Figure 14-38 shows a typical bimetallic disk-type overload protector. This overload protector is connected in the common line and mounted on the compressor motor shell.

CAPACITORS

In hermetic refrigeration and air-conditioning work, capacitors are

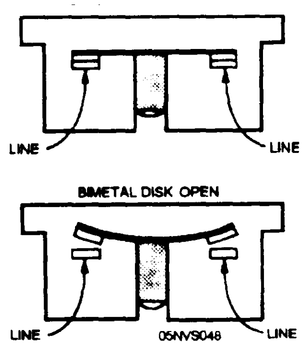

Figure 14-38.—Bimetal disk-type overload.

identified in two groups: start capacitors and run capacitors. These may be identified further as dry capacitors that are used for intermittent operations (start capacitors) and electrolytic capacitors that are used for continuous operation (run capacitors).

START CAPACITORS

Start capacitors are connected in series with starting windings. By looking at figure 14-39, you can see the location of the start capacitor in a circuit. Because a start capacitor is placed in series with one of the two stator windings, the current will lead, as compared to the current going directly to the connected stator winding. This, in turn raises the attraction of one stator winding over the other, allowing the motor to begin turning. Figure 14-39(A) shows that stator winding 2 is stronger than stator winding 1. Therefore, the motor begins to turn in the direction of the stronger attraction. Once the initial starting of the motor is completed, the start capacitor is removed from the circuit

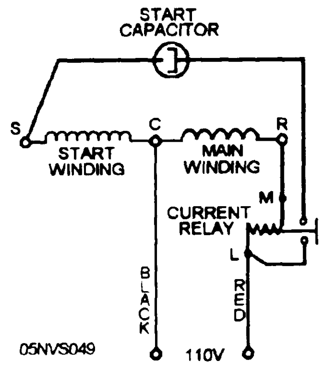

Figure 14-39.—Various types of capacitors.

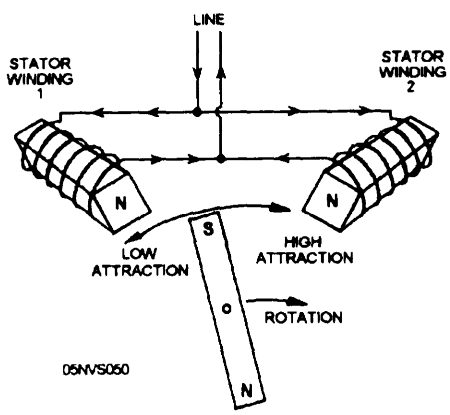

Figure 14-39.—Motor starting.

RUN CAPACITORS

Run capacitors are connected in the circuit between the line side of the starting and running windings. This type of capacitor serves to provide a smoother and quieter operating motor.

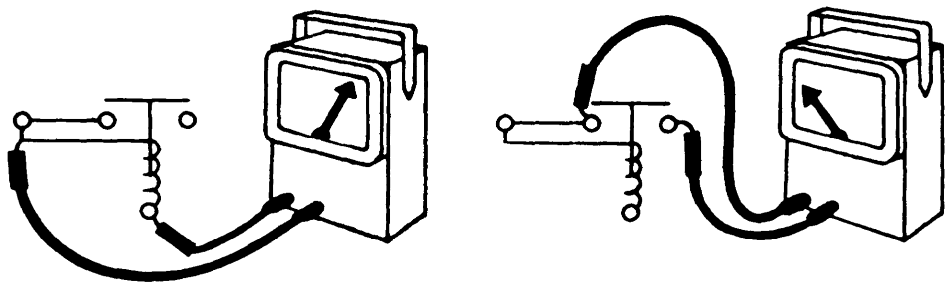

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Figure 14-40.—Testing a starting relay with an ohmmeter.

EQUIPMENT AND TEST PROCEDURES FOR ELECTRICAL CIRCUIT COMPONENTS

The equipment and procedures for testing circuit components such as starting relays, overload protectors, and capacitors are discussed as follows.

STARTING RELAYS

Starting relays can be tested two ways with an ohmmeter. The meter can be used to check across the relay contacts, or it can be used to check across the relay coil. This does not apply to thermal relays. Figure 14-40 illustrates procedures for these tests.

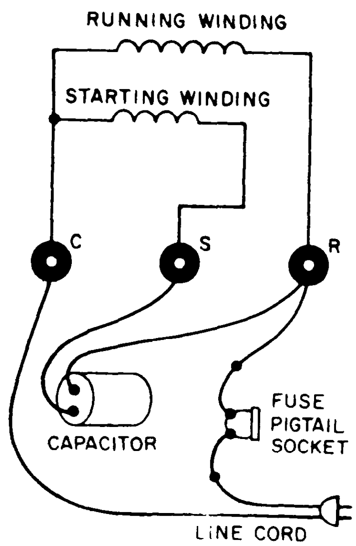
When you check the relay contacts, you must know if the contacts are normally open or normally closed. Voltage relay contacts and thermal relay contacts are normally closed, whereas current relay contacts are normally open. The meter reading should indicate continuity through voltage and thermal relays since the contacts are normally closed. On the other hand, if the meter indicates continuity through the normally open contacts of a current relay, the contacts are probably fused together.

Another method of checking starting relays is by using a test line cord and fuse combination to isolate the relay. Figure 14-41 illustrates the procedure used in making this test. Obtain a capacitor of the approximate size used with the compressor motor. Connect it from the hot side of the running winding to the hot side of the starting winding. Connect the test line to the motor terminals as illustrated in the figure and plug it in. If the compressor is good it should start running. After a short time, disconnect the capacitor. The compressor should continue to speed up and run normally. This procedure has accomplished manually what a properly functioning starting relay is supposed to accomplish. If the motor failed to start normally before the check, the relay is bad.

Voltage and current relay coils can also be tested for resistance with an ohmmeter. When the coil is burned out, the meter indicates no resistance or an open coil. Commercial starting relay testers are available from several manufacturers.

OVERLOAD PROTECTORS

Questionable Klixon external overload protectors should be replaced with new ones. If the



87.255

Figure 14-41.—Procedures for checking a starting relay with a test line.

motor then operates properly, the old Klixon (protector) should be destroyed. Klixons can also be checked with an ohmmeter. Since the contacts are closed at ambient temperature, the meter should show continuity. When the meter shows an open, the Klixon should be replaced and destroyed.

Internal current temperature overloads can be tested by making continuity checks. Continuity checks must be made across terminals C and S, C and R, and S and R. When both C and S and C and R are open and continuity is indicated across S and R, the protector is open. When the temperature is normal and the continuity test indicates the overload contacts are open, the motor compressor assembly must be replaced. When the operating temperature is normal, the internal current temperature overload contacts should be closed.

CAPACITOR TEST

The best test for a questionable motor capacitor is to try a new one of the correct size. If the motor operates properly, the old capacitor is defective and should be destroyed. Capacitors can also be tested with ohmmeter. First, the power must be turned OFF and the capacitor disconnected and discharged with a 2 watt 20,000 ohm resister. Set the meter on the 0 to 10,000 ohm scale and touch the meter probes to the capacitor terminals. If the digital display indicates 0 or low resistance and then climbs towards high resistance, the capacitor is good. If the display indicates 0 or low resistance and stays there, the capacitor is shorted. If the display stays blank, the capacitor is open. Figure 14-42 shows these procedures.

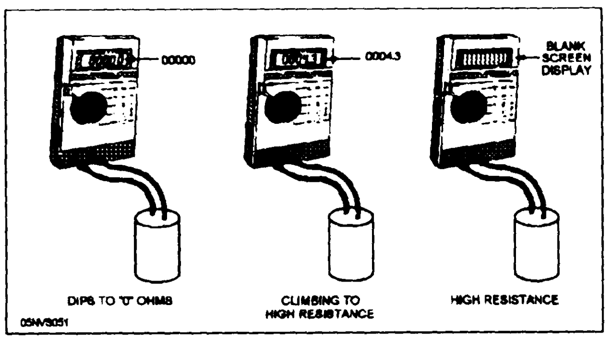


Figure 14-42.—Testing capacitors with an ohmmeter.

HERMETIC ELECTRICAL SCHEMATIC WIRING DIAGRAMS

All wiring circuits are built around four requirements: a source of electrons, a place for them to flow, a path for them to follow, and a load to make use of and control the flow. The schematic wiring diagram puts the symbol and line representation on paper in a manner that allows instant identification of all four requirements. It tells the service member how and why a unit works as it does.

In the schematic wiring diagram, the source of electrons is a line drawn on one side of the diagram and it is usually designated as L1. Any and all points on this line have a surplus of electrons. On the opposite side, a line is drawn representing a shortage of electrons and it is usually designated as L2. There is a potential for electron flow between the two wires represented by L1 and L2. When a load is inserted between L1 and L2, current flows and the load functions.

Figure 14-43 is a typical schematic diagram for a hermetic electrical system. Figure 14-44 is a wiring schematic and a wiring detail for a typical room air-conditioner.

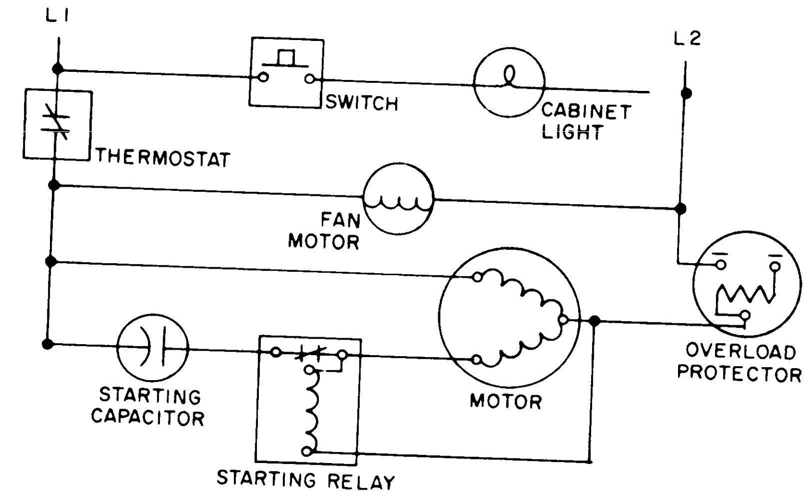


Figure 14-43.—Typical hermetic system schematic wiring diagram. 87.257

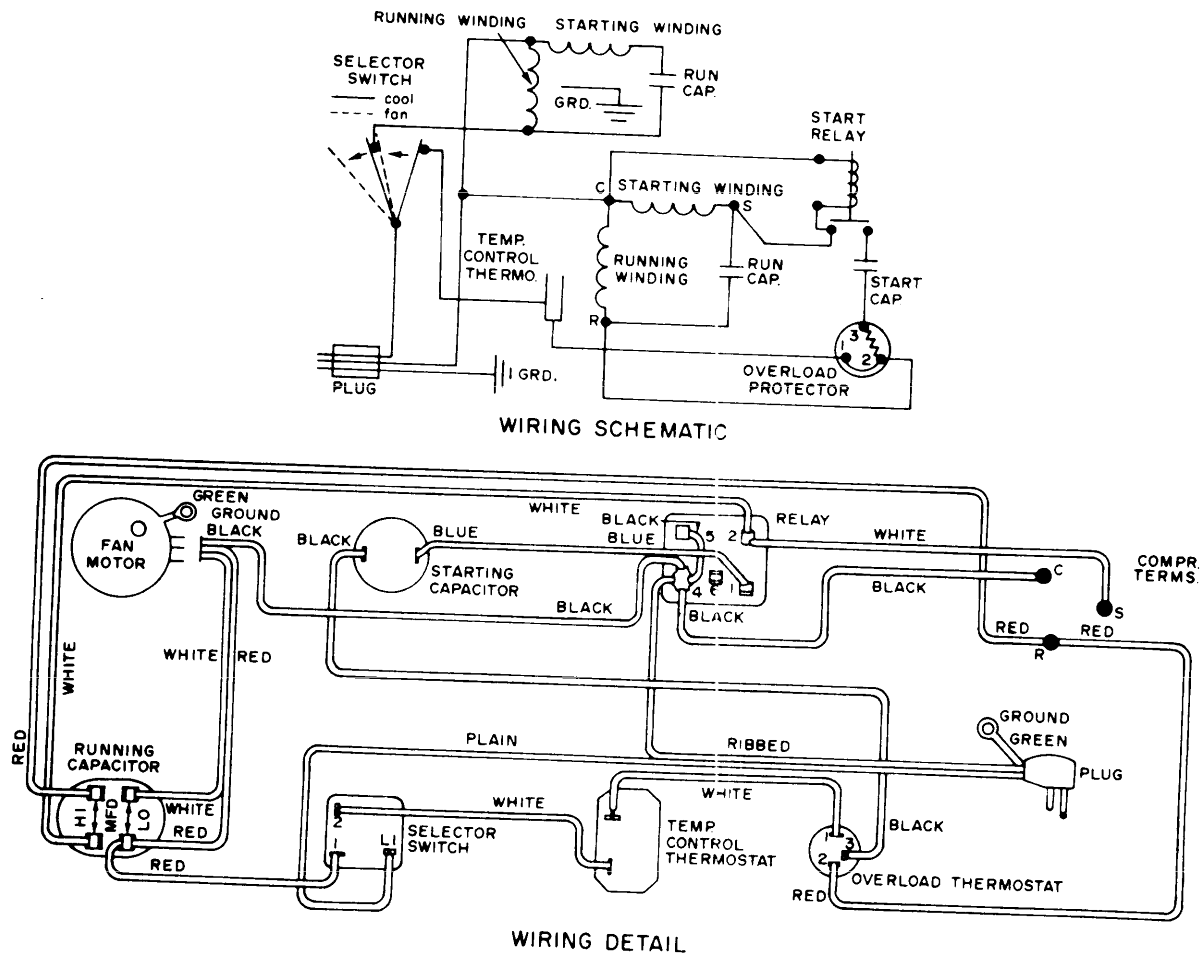


Figure 14-44.—Wiring schematic and detail for a typical room air-conditioner. 87.258